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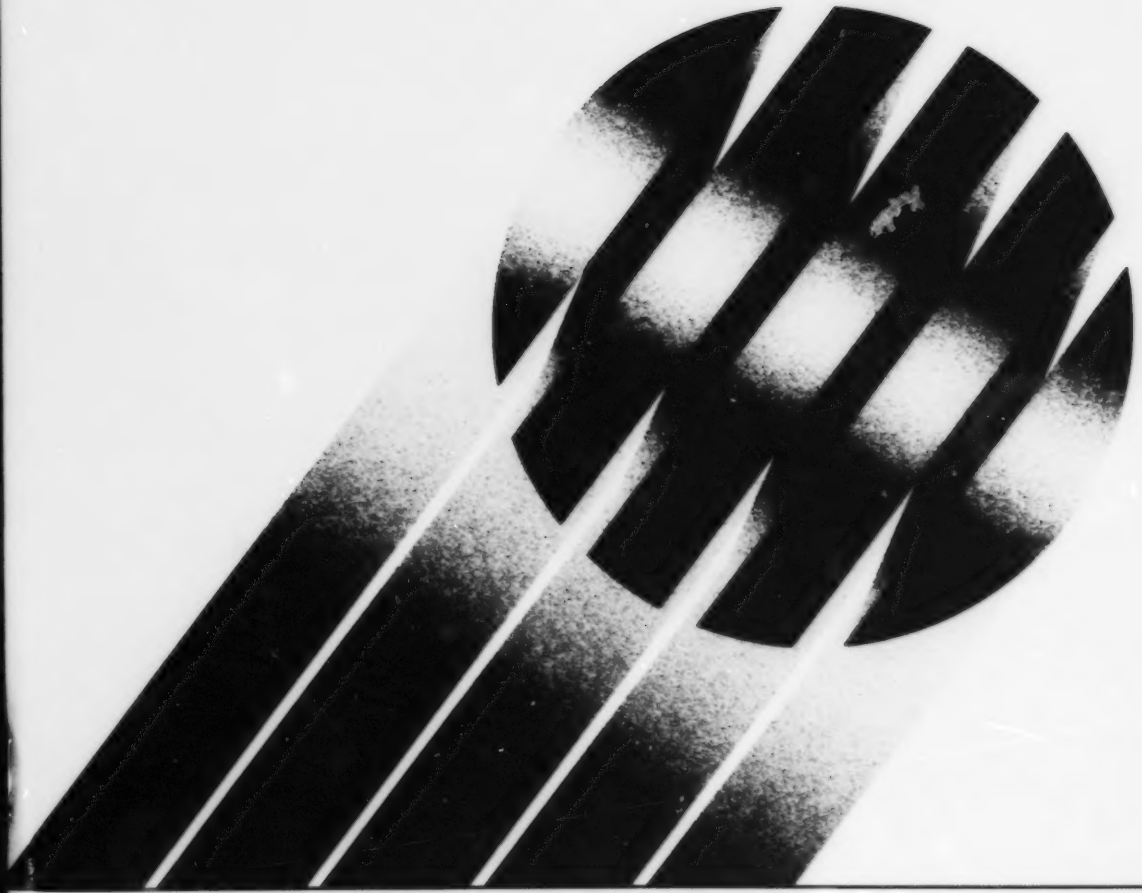
Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

SUMMARY REPORT NO. 8: TALC AND PYROPHYLLITE

R.K. COLLINGS AND P.R.A. ANDREWS
Mineral Processing Laboratory

MINERAL SCIENCES LABORATORIES



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March 1990

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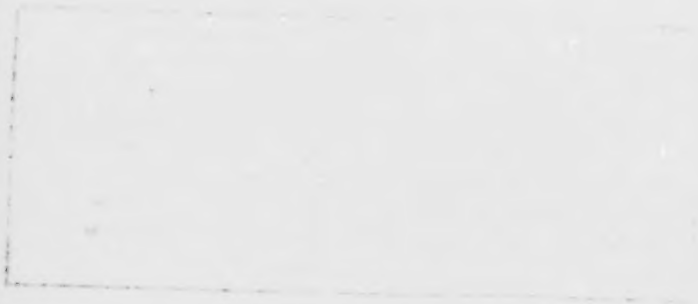

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SUMMARY REPORT NO. 8: TALC AND PYROPHYLLITE

by

R.K. Collings* and P.R.A. Andrews**

Abstract

Talc is a hydrated magnesium silicate and pyrophyllite the hydrated aluminum silicate analogue, so that each mineral possesses similar physical properties.

Talc occurs in various provinces of Canada, but deposits of commercial interest are confined to Quebec, Ontario and British Columbia. There are four current producers of talc, two in Ontario and two in Quebec. Pyrophyllite occurs mainly in Newfoundland and British Columbia; there is only one producer, in Newfoundland.

Talc is valued for its softness, smoothness, dry lubricating properties, whiteness, chemical inertness and foliated structure. Its most important and best known applications are in the cosmetics and pharmaceutical industries, although its use as a filler and extender in paints is also important. The mineral is used in the manufacture of ceramics, fertilizers and insecticides, as a filler and dusting agent in roofing felt, by the rubber and plastics industries, and in numerous other applications.

Pyrophyllite is used in some of the same applications as talc. The principal use for pyrophyllite is in refractory applications, since it does not flux very easily when fired.

Talc and pyrophyllite ore samples have been studied extensively at CANMET and by its predecessor, Mines Branch, over the past sixty years. Summaries of processing data and test results are presented in four Appendices.

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RAPPORT SOMMAIRE N° 8: TALC AND PYROPHYLLITE

par

R.K. Collings* et P.R.A. Andrews**

Résumé

Le talc est un silicate de magnésium hydraté, et la pyrophyllite, un silicate d'aluminium hydraté, de sorte que les deux minéraux possèdent des propriétés physiques semblables.

Il y a du talc dans plusieurs provinces canadiennes, mais les gisements d'intérêt commercial se trouvent au Québec, en Ontario et en Colombie-Britannique. Il y a actuellement quatre producteurs de talc, deux en Ontario et deux au Québec. La pyrophyllite est concentré à Terre-Neuve et en Colombie-Britannique; il n'y a qu'un producteur, à Terre-Neuve.

La talc est recherché pour sa douceur, sa plasticité, ses propriétés lubrifiantes à sec, sa blancheur, son inactivité chimique et sa structure feuilletée. Il est surtout utilisé dans la fabrication de produits de beauté et de produits pharmaceutiques, même s'il sert souvent de matière de charge et d'allongement dans les peintures. Il est utilisé dans la fabrication des céramiques, des engrais et des insecticides, comme agent de charge et dépoussiérant dans le carton feutré de toiture, par les industries du caoutchouc et des plastiques et dans de nombreuses autres applications.

Certaines applications de la pyrophyllite sont les mêmes que celles du talc. Elle est surtout utilisée dans les produits réfractaires parce qu'elle se liquéfie difficilement sous l'action du feu.

Au cours des 60 dernières années, des échantillons de talc et de pyrophyllite ont été étudiés en profondeur à CANMET et à la Direction des mines qui a précédé. Des résumés de données de traitement et de résultats d'essais sont présentés dans quatre annexes.

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INTRODUCTION

A CANMET survey of Canadian industrial mineral producers (1) identified a number of problems specific to the industry as well as potential opportunities for further development and expansion. The response to this survey and subsequent discussions with industry and government specialists identified a requirement for information in a number of areas. These areas included mineral deposits, processing, beneficiation studies and new developments, as well as information on product specifications and potential markets for Canadian industrial minerals.

Related information on file at CANMET, and as available from provincial government offices and the private sector, were subsequently compiled in a series of Summary Reports on a number of industrial minerals. The information for each mineral pertains to mineral occurrences, deposits of specific interest, current activities, product uses and specifications, process technology, and summaries of past testwork on specific deposits by CANMET and others. This report, Summary Report No. 8: Talc and Pyrophyllite, is the eighth in the series, the previous reports were Barite, Celestite, Fluorite, Silica, Mica and Vermiculite, Graphite, Gypsum and Anhydrite.

TALC

Mineralogy and Geology

Talc is a hydrated magnesium silicate which, when pure, has the formula $Mg_3Si_4O_{10}(OH)_2$ corresponding to a theoretical composition of 31.7% MgO, 63.5% SiO_2 and 4.8% H_2O. Substitution within the talc lattice is not common, although minor amounts of iron may replace magnesium, and very small amounts of aluminum may substitute for magnesium and silicon. Commercial grades of talc rarely approach the theoretical composition of the pure mineral (see Table 1) because of the presence of other, intimately associated minerals.

Table 1 - Typical chemical analyses of some commercial grades of talc (2,3)

Oxide	% Weight				
	1	2	3	4	5
SiO_2	59.40	60.47	57.52	39.8	42.73
Al_2O_3	0.68	1.55	3.08	0.6	1.17
Fe_2O_3	0.18	1.32	0.83	6.7	4.93
CaO	0.66	0.65	0.53	0.6	0.10
MgO	31.40	30.75	31.60	33.1	33.16
LOI	7.10	5.69	6.48	19.7	17.69

1. Chinese micronised talc MW4.
2. Italian (Pinerolo) talc Extra A.
3. Luzenac talc grade OOS.
4. Norwegian ground talc FWXO.
5. U.S.A. Grey talc.

Talc has a pearly lustre, greasy feel, and may be white, pale green or grey in colour. Talc possesses good cleavage, is chemically inert, has low thermal and electrical conductivities, a high fusion point and a hardness of 1.0 on the Moh scale.

There are several varieties of talc including steatite or soapstone, a massive variety that is mostly white or grey in colour. Potstone is an impure massive talc or soapstone varying in colour from greyish-green to brownish-black. Rensselaerite is a variety of soapstone pseudomorphous after pyroxene; French chalk is a steatite originally used by tailors for marking cloth; indurated talc is an impure slaty variety which is somewhat harder than French chalk (4).

Talc deposits usually occur associated with either altered ultrabasic rocks or metamorphosed dolomitic limestones. In altered ultrabasic rocks, talc occurs as an alteration product of magnesium-rich silicates such as olivine, diopside and enstatite. Talc formed by the low-grade thermal metamorphism of dolomitic limestones is characterized by silica, which was present in the original sediment or introduced by hydrothermal solutions. MacLean (5) notes

four common geological settings for talc formations in British Columbia as follows: within regionally metamorphosed and hydrothermally altered ultramafic rocks; in association with chloritic schists; in association with dolomite and magnesite; and in association with mafic volcanics.

Talc occurs associated with a wide variety of minerals, some of which are reported for various commercial grades of talc in Table 2.

Table 2 - Typical mineralogical compositions of some commercial grades of talc (2,6)

Mineral	% Weight				
	1	2	3	4	5
Talc	95	90	89	86	49
Chlorite	3	4	8	3	15
Magnesite	-	0.6	-	2.5	31
Dolomite	1	0.8	-	2	-
Tremolite	-	-	-	-	trace
Serpentine	-	-	-	-	*
Quartz	-	trace	trace	trace	-
Opaques	-	-	-	-	trace

*Serpentine identified by X-ray diffraction but included by thermogravimetry in chlorite figure.

1. Chinese talc - cosmetic grade.
2. Italian (Pinerolo) talc - cosmetic grade.
3. French (Luzenac) talc - high quality.
4. U.S.A. Vermont talc.
5. Norwegian talc - industrial grade.

Principal Occurrences

Talc occurrences or deposits of interest in Canada have been recorded in Newfoundland, Quebec, Ontario, Manitoba, Saskatchewan and British Columbia. The more significant deposits are noted on the map in Figure 1.

Newfoundland

Hibbard (7) notes the occurrence of asbestos-associated talc in the ultramafic rocks of the Baie Verte peninsula, and identifies a prospect at Timms Brook as containing relatively abundant talc mineralization. A high-grade talc deposit was recently discovered by Noranda Exploration Company during evaluation of the Devil's Cave gold property, 7 km north of Timms Brook (8). Talc-magnesite zones of possible economic interest have been identified in the Great Bend ultramafics in east-central Newfoundland, 75 km southwest of Gander (9).

Quebec

Talc deposits in Quebec are essentially confined to occurrences associated with the extensive development of serpentine and altered ultrabasic rocks in the Eastern Townships region, south of the St. Lawrence River.

Wilson (10) and Spence (11) describe a number of talc occurrences and deposits in various townships including Sutton, Potton and Bolton, Brome county; Ireland, Inverness, Thetford and Leeds, Megantic county; and Broughton, Beauce county.

In a detailed report on talc occurrences in southeastern Quebec, Hebert (12) lists ninety-six occurrences and deposits in the Magog-Thetford Mines region. Apart from deposits currently operated by Luzcan Inc., southwest of East Broughton, and by Bakertalc Inc.,

Figure 1. PRINCIPAL TALC AND PYROPHYLLITE DEPOSITS IN CANADA

LEGEND

Talc Deposits

NEWFOUNDLAND

1. Timms Brook
   Devil's Cove (Noranda - Corona)
2. Great Bend

QUEBEC

3. East Broughton (Luzenac)
   Broughton Twp. (Luzenac)
   Coleraine Twp. (Asbestos Corp.)
4. South Bolton (Bakertalc)

ONTARIO

5. Madoc (Canada Talc)
6. Penhorwood Twp. (Luzenac)

MANITOBA

7. Iskwasum Lake

SASKATCHEWAN

8. Mosher lake

BRITISH COLUMBIA

9. Mount Whymper
10. View
11. Sovereign Creek (Trifco)
12. McGillivray, Lucky Jane
13. Hope
14. Nahatlatch River, Gisby (Pacific Talc)
15. Eagle, Invereck, Leech River, Ironclad

Pyrophyllite Deposits

NEWFOUNDLAND

A. Fox Trap
   Trout Pond
   Dog Pond (Newfoundland Minerals)

QUEBEC

B. St. Nicholas
C. Stanstead Twp.
D. Carpentier Twp.

BRITISH COLUMBIA

E. Riverdale
F. Pyro Sound
G. Kyuquot Sound, Island Copper

● = TALC

○ = PYROPHYLLITE

west of South Bolton, two other deposits are identified in the Thetford Mines area with good potential for development. The first, in Broughton township, is at the site of the former Montreal asbestos open-pit mine. The talc occurs in a talc carbonate schist zone along the northern edge of the pit. The zone has a width of 60 m and a strike length of 350 m. The second occurrence is in Coleraine township at the site of the Beaver asbestos open-pit mine. A diamond drill program conducted in 1977-78 by Asbestos Corporation resulted in the discovery of a large talc-carbonate-schist zone, at depth, along the southern face of the pit. These occurrences are noted in Figure 1.

Ontario

Wilson (10), Spence (11) and Hewitt (13) note numerous occurrences of talc in southern and northwestern Ontario; in Hastings, Frontenac, Lennox, Addington and Lanark counties, and in the Sudbury and Kenora districts.

The more important occurrences are in Hastings county, in Madoc, Huntington, Elzevir and Grimsthorpe townships. Commercial production of talc has been carried on in the Madoc area for over 80 years, production being largely from the Henderson mine, first operated in 1896, and the Conley mine, first operated in 1911. Talc continues to be produced today at Madoc from these two mines as well as from a nearby talc deposit which is operated as an open pit. An important occurrence of talc was recently discovered in Penhorwood township, south of Timmins. This deposit is currently being mined by open-pit methods.

An excellent compilation of talc occurrences in southeastern Ontario was prepared in 1989 under the Canada-Ontario Mineral Development Agreement (14).

Manitoba

Talc associated with quartz, dolomite and iron oxides has been reported at Iskwasum Lake, and along the Grass River in the Flin Flon-Snow Lake area of northern Manitoba (15).

Two types of talc were identified: a fine-grained platy talc in a talc-carbonate rock and a coarse-grained platy talc in veins up to 10 cm in width. Samples analyzed by X-ray diffraction varied from 40 to 55% talc, 15 to 50% dolomite and 1 to 43% magnesite. Further information on these and other occurrences will be included in a final Canada-Manitoba MDA report, which is scheduled for publication in mid-1990 (16).

Saskatchewan

A large body composed of a mixture of talc and magnesite underlies part of Mosher Lake in northeastern Saskatchewan, and outcrops on a number of islands over a strike length of 3000 m. Diamond drilling near the south end of the deposit indicated a width of about 65 m (17). Beneficiation tests undertaken by CANMET showed that flotation could be used to achieve a separation of the talc from magnesite. Mineral analyses indicated a typical sample to contain 54% talc, 45% magnesite and 1% graphite (18). Talcy andesite, talc and serpentine were encountered in the same area, southwest of Wolverine Lake, over a width of 12 m during a 1952 diamond drilling programme by Hudson Bay Mining and Development Company Limited (19).

British Columbia

Spence (11) lists five principal occurrences of talc in British Columbia, one on Vancouver Island at Eagle, near Victoria, and four in the southern part of the province: one near McGillivray, west of Lillooet; one at Gisby, near Boston Bar; one near Hope; and one east of Golden, near Mount Whymper. MacLean (5) lists thirty-eight deposits including those

noted by Spence, and subdivides them on the basis of four geological types which are shown in Table 3. Four of these deposits, T-20(Eagle), T-21(Invereck), T-22(Leech River) and T-31(Ironclad) are located in the southeastern end of Vancouver Island within 50 km of Victoria. The remainder are scattered throughout the central and eastern portions of the province from the U.S.A. - Canada border northwesterly to the Yukon border. Although none of these deposits is currently being developed, several, e.g., T-20(Eagle), T-23(Lucky Jane), T-24(Gisby) and T-32(View) were operated in the early 1900s to provide talc for ceramics and for various filler applications.

Several contain significant quantities of relatively high-grade talc, e.g., T-6(Barbara Ann); a sample of which taken by the B.C. Ministry of Mines in 1950-51 analyzed 71% talc, 14.5% magnesite, 2.5 calcite and 6.3% magnetite. A sample from a deposit designated T-11(H) analyzed 62% talc, 30% magnesite, 8% chlorite and 5.8% iron oxide; reserves were estimated at 30,000 t per vertical metre. In the T-12(Rawhide) deposit, a 15 to 30 m wide zone is exposed over 120 m; a random sample analyzed 95% talc and associated tremolite. A drilling program in 1978 indicated that T-15(Sovereign Creek) was a high-grade talc schist containing up to 95% talc in association with an albite-syenite intrusion. Three holes, also drilled in 1978, showed major talc intersections for T-25(J and J) with grades ranging from 50 to 60% talc, with 25 to 35% chlorite and 5 to 10% dolomite and magnesite; reserves of talc were estimated at 420,000 t in 1989. A drilling program in 1979, at T-38(Chu-Chua), found talc in four holes; reserves were estimated at 180,000 t.

A more detailed account of talc occurrences in British Columbia can be found in MacLean's excellent report.

Table 3 - Talc deposits in British Columbia (5)

Ultramafite-Hosted Talc	Schist-Hosted Talc
T1 White's Camp	T20 Eagle
T2 Phoenix/Athesran-Jackpot	T21 Invereck
T3 Asbestos Group	T22 Leech River Group
T4 Highland Surprise	T23 Lucky Jane
T5 Chrome-Vanadium	T24 Gisby
T6 Barbara-Ann	T25 J&J
T7 Standard	T26 Cawston
T8 Monarch	T27 Duncan Lake
T9 Aurum	T28 Silver Cup
T10 Clover Leaf	T29 Homestake
T11 H	T30 Kirkup
T12 Rawhide	T31 Ironclad
T13 Cadwallader Creek	
T14 St. John Talc	Dolomite-Hosted Talc
T15 Sovereign Creek	
T16 Baptiste	T32 View
T17 Humphrey	T33 HB
T18 Jed	T34 Dolo
T19 Cassiar	T35 Illecillewaet
	T36 Silver Moon
	T37 Gold Dollar
	Mafic-Volcanic-Hosted Talc
	T38 Chu-Chua

Uses and Specifications (20,21)

Talc is valued industrially for its softness, smoothness, whiteness, high slip or lubricating power, foliated or lamellar structure, high surface area, chemical inertness, oil absorption properties, low electrical and heat conductivity, high refractoriness and low thermal expansion. These properties are all related to its crystal structure and composition (2).

Talc in a finely ground form is used as an additive material in a wide variety of products; in ceramics, cosmetics, paint, paper, plastics, roofing and rubber. Minor amounts of talc are also used for sculpturing block, foundry facings, rice polishing, and as filler or additive in asphalt, caulking, floor tile, insecticides, joint compounds, refractories and stucco.

Ceramics (22,23)

Ceramic-grade talc is used to produce wall tile, electrical ceramics, sanitaryware, stoneware, opaque glasses, vitreous china, catalytic converters and other whitewear. Wall tile, electrical ceramics, sanitaryware and stoneware are the most common uses for ceramic-grade talc.

The purpose of talc in pottery, tile and dinnerware compositions, is to lower firing temperatures to control thermal expansion and shrinkage on firing, to control crazing in glazes, and to improve the translucency, whiteness and toughness of finished products. Pottery compositions may include up to 40%, whereas dinnerware bodies usually contain only 10 to 15% talc. Talc content may be 40 to 50% for catalytic converters and may approach 70% for ceramic insulators and ceramic tiles.

Talc is a major constituent in steatite and cordierite technical ceramics which are mainly used as insulators for the electrical industry. Normal steatite, which usually consists of talc, clay and feldspar, may replace porcelain for low tension pressings and extrusions, and for some high-tension insulators.

Low-loss steatite electroceramics, which are usually fairly small, are produced by dry-pressing or extruding a finely ground mixture of 70 to 90% talc with ball clay and about 10% barium carbonate. Firing is conducted at temperatures within the range 1200 to 1350°C. Steatite is the most widely used ceramic in electronic applications, where it is used in coil formers, stand-off insulators, condenser-end plates, panel bushes, valve electrode spacers and valve-holder bases.

Talc mixed with clay and alumina and fired at 1250 to 1400°C produces a cordierite body, which has a very low thermal expansion, high thermal shock resistance and good electrical properties. Cordierite bodies are used for coil formers, electric water-boiler insulators, arc chutes, fire-bars, fuse cores, oil burner ignition insulators, rheostat blocks, resistor bobbins and spools, and in the manufacture of saggars and other items of kiln furniture. Talc is also used in the manufacture of steatite ceramic grinding balls (2).

Specifications for the ceramics industry vary considerably and depend on the particular application. For low-loss electroceramics, CaO, Fe_2O_3 and Al_2O_3 should be low; maximum CaO content should range from 0.1 to 1.0%, Fe_2O_3 from 0.1 to 1.5%, and Al_2O_3 from 0.1 to 2.5%.

The talc should fire to a white product; generally speaking iron and manganese are undesirable as they cause discolouration. Uniformity in the quality of supplies is also important. The desired composition of powdered talc for electrical insulating purposes is:

SiO_2: 60%
MgO: 30%
Al_2O_3: 2.5%
CaO: 1.0%
Fe_2O_3: 1.5%
$Na_2O + K_2O$: 1.0%
Loss on ignition: 6.0%
Acid soluble lime: 1.0%

For cordierite ceramics, talcs may have a more variable composition and higher impurity levels are tolerated. Non-flaky types of talc are required to prevent lamination and to give a uniform bulk density, so that pressed articles have the correct size and shape when fired (2). The particle size for ceramic-grade talc is 99% minus 75 μm, and 95% minus 44 μm, with most between 5 and 15 μm (24).

Cosmetics and Pharmaceuticals (6)

Cosmetic uses for talc encompass all varieties of face powders and body-dusting powders. Cosmetic-grade talcs also include talc used in pharmaceutical products and medicinal tablets, creams and soaps. Talc is the main ingredient (more than 50%) in most cosmetics; the remainder being a combination of oxides, sterates, perfumes and starch. Talc is used in cosmetics to impart softness and lubricity, to improve the hiding power of the product, and to aid in retaining added perfumes (22, 25). Cosmetic talcs (and talcs used as fillers in pharmaceutical products) must meet strict quality standards. A summary of selected specifications for cosmetic-grade talc is reported in Table 4.

Paint (2,6,22,27)

The paint industry is also an important consumer of talc, chiefly as an inert extender or filler. Talc is valued because of its excellent white colour, easy dispersibility in water and oil systems, and foliated structure which gives good flatting and suspending properties. The paint category covers all varieties of paints: water-based, oil-based, synthetic resin paints and lacquers. In North America, talc is used primarily in topcoats, industrial paint and industrial primers (26).

Talc helps to smooth ridges left during brush applications, and absorbs oil better than most minerals. Talc competes with calcium carbonate, kaolin, barite and mica as a filler and extender in paint (28).

Table 4 - Selected specifications for cosmetic-grade talc (24,25)

Property	Specification
Mineralogical content	A minimum of 90% talc with trace amounts of chlorite, magnesite, dolomite and calcite.
Macroscopic appearance	A powder free from visible extraneous matter.
Microscopic appearance	Cosmetic talc is composed predominantly of translucent, laminar, irregular but substantially isodiametric particles not normally exceeding 60 μm in the maximum dimension.
Colour	White or "off white": shade criteria to be agreed between buyer and supplier.
Odour	Virtually odourless.
Texture and slip	Free from gritty particles by palpation.
Screen test	100% pass through 150 μm and 98% minimum through 75 μm; finer grades to be as specified by the buyer.
Loss on drying	Losses not more than 0.6% when dried at 105°C to constant mass.
Acid-soluble matter	6% maximum: there must be no odour of H_2S.
% Acid Sol. Fe_2O_3	0.2 maximum
Sulphides	Absent
Water-soluble matter	Boil 5.0 g with 25 mL water for 30 minutes under a reflux condenser, filter, evaporate the filtrate to dryness and dry at 105°C. The residue should weigh not more than 10 mg.
Tapped density	0.95 to 1.20 g/mL
Lead	20.0 ppm maximum
Arsenic	3.0 ppm maximum
pH	6.5 to 9.5
Slip	Excellent
Lustre	Excellent
Identification	By X-ray diffractometry or infra-red spectroscopy
Amphibole minerals	Not detected by the instrument and technique described (TPF method 78 or other method of suitable accuracy and sensitivity).

Talc is selected for use in paints based on chemical composition, oil absorption, particle size, particle shape, size distribution, refractive index and water-soluble matter content. A summary of selected specifications for paint-grade talc is reported in Table 5.

Table 5 - Selected specifications for paint-grade talc (2,6,24)

Property	Specifications
Mineralogical content	No abrasive materials
MgO	24 to 32%
SiO_2	50 to 65%
Lime	9% maximum
Mg and Ca silicates	88% minimum
CO_3	6% maximum
Loss of ignition	7% maximum
Moisture and other volatile matter	1% maximum
Water-soluble matter	1% maximum
Particle shape	varies
Particle size	44 to 2.5 μm
Average size	10 to 5 μm
Specific gravity	2.75 to 2.85
Refractive index	1.59 to 1.75
Oil absorption	28 to 72*
Brightness	65 to 90
Colour	white or near white

*g of oil per 100 g of talc

Plastics (2,6,22,27)

Talc is used as an additive mineral in both thermoplastics and thermosetting materials to improve chemical and heat resistance, impact strength, dimensional stability, stiffness, hardness, thermal conductivity, tensile strength, creep resistance and electrical insulation properties (29-31).

The chief use for talc, as a filler, is in polypropylene. It is also used as a filler in polyvinyl chloride and in polyester resin-based sealing compounds; perhaps one of its best known applications in this area is in car body patching compounds. As a bulk filler, talc reduces the amount of resin required in the product and thus reduces costs. Talc also imparts desired physical, electrical and processing properties to the plastic.

Talc is one of the few minerals used by the plastics industry as a reinforcer. Its platy nature provides rigidity to the composite (29). Plastics with talc fillers exhibit higher stiffness and creep resistance at ambient and elevated temperatures than do plastics with mineral fillers such as calcium carbonate. For example, a polypropylene with a 40% loading of talc filler has a stiffness three times that of polypropylene with no filler, and 1.5 times that of polypropylene with a 40% loading of calcium carbonate (29).

Talc is also used as a dusting agent to reduce friction between plastic-coated electrical wires in electric cables and cords.

Talcs selected as fillers are chosen according to colour, particle size and shape, resin absorption, moisture and iron content. The talc must be free of iron and abrasive materials and should be 10 μm or less in particle size. Platy talc offers better heat resistance and is softer than acicular talcs; however, acicular talcs offer better reinforcement.

Talc competes with carbonates, clays, feldspar, mica, silica and wollastonite as a mineral filler.

Pulp and Paper (6,22)

Talc is used in a variety of paper products, including wrapping paper, writing paper, packaging paper and paperboard (32). The principal use is for pitch control; the pitch adheres to the surface of the talc and is dispersed throughout the paper rather than agglomerating to form spots in the paper products. The reduction of agglomeration also

helps prevent the pitch from being deposited on equipment. Talc fills the interstices between the cellulose fibres, reduces the transparency of the paper, increases brightness, improves ink reception, increases density, and reduces the demand for more expensive paper pulp (32). Printing and writing papers can contain up to 30%, paperboard products 10%, and newsprint 8% talc as filler. Talc is selected as a filler because of its high whiteness, non-abrasive nature, chemical inertness, and availability in ultrafine particle size. Minerals that compete as paper fillers include calcium carbonate, kaolin and titanium dioxide (32).

Specifications for the paper industry stipulate that talc should contain less than 5% carbonate minerals and be free of abrasive matter. Size specifications for filler applications are that maximum particle size should not exceed 5 μm, coater particle size should not exceed 10 μm and, as a pitch control agent, particle size should be about 1 μm.

Insecticides (6,22,33)

The insecticides category includes fertilizers, insecticides, herbicides and fungicides. Talc serves principally as a carrier to distribute the fertilizer, insecticide, herbicide, or fungicide, and to dilute the chemical to prevent damage from concentrated dosages. Talc is also used as an anti-caking agent for dry compounds. Talc is useful because it is absorbent, disperses in liquids, does not react with insecticides, does not clog equipment when finely ground, and does not abrade nozzles. Fuller's earth is the leading competitor with talc, followed by kaolin, bentonite, diatomite, perlite, sepiolite and attapulgite.

Specifications for insecticide use are generally less rigid than for other uses. The talc should be fine and off-white colour is usually acceptable, although the presence of abrasive matter is to be avoided (2).

Roofing Felt (22,27)

Talc is used in the manufacture of roofing products as both a filler and a dusting agent. It is added to asphalt and bitumen to increase viscosity, melting point, hardness, and resistance to stress and weathering. Talc is used to dust the surfaces of asphalt roofing products to prevent sticking during manufacture and storage. Talc used by the roofing industry generally is ground to minus 180 μm and, although usually low grade, it must have high absorbency.

Specifications for roofing felt are similar to those for insecticide use. A fine, off-white colour is generally acceptable, but no abrasive matter should be present (2).

Rubber (2,6,22)

Talc is used by the rubber industry in the production of tires, tubing, sheets, valves, flooring products, backing for textiles, and for electric cable insulation. Talc is used as a dusting agent to prevent sticking of the rubber to the mould, to reduce the amount of expensive resins used for products, to increase the stiffness of uncured compounds, and to reinforce rubber products. Where rubber articles are vulcanized in steam autoclaves, talc is used to support the articles in the pans. This method of vulcanization, however, is being superseded by continuous processes which do not require talc.

Talc for use in rubber should be less than 45 μm in size and contain no abrasive minerals that could cause wear of the processing equipment. The talc should be white when used as a filler in latex fabric backings, but colour is not critical for most other uses; manganese and copper must be low. Talc competes with calcium carbonate, kaolin and silica in this application.

Miscellaneous

Low-grade talc is used as a dusting agent for gypsum boards and as a filler in drywall sealing compounds, floor tile and asphalt-pipeline enamels.

Low-grade talc is used as a refractory filler in a wide variety of core and mould coatings for both non-ferrous and ferrous foundry castings. Talc, however, cannot be used for steel castings since even the most refractory grades would fuse or melt at the high casting temperatures. A typical chemical analysis of talc used in foundry coatings is: 57% SiO_2, 32% MgO, 3% Al_2O_3; the remainder consisting of FeO, CaO and ignition loss. Chemical composition is not, however, critical unless it causes a significant reduction in refractoriness. This may have little effect when used on most non-ferrous metals, but its effect will be more marked when used in mould coatings in iron foundries. Talc for foundry use must pass 75 μm (2).

Soapstone is easily carved and sculptured and has been used for centuries for interior ornamental work; indeed, small quantities of roughly squared blocks are still sold for sculpture work. The specifications for sculpturing are that the talc block should be free of cracks and other imperfections that could reduce its integrity. The most desirable colour for sculpturing block is apple green, although dark green talc blocks are also used.

Mining (6,21)

Talc is obtained by either open pit or underground mining. Open pit mining involves removal of overburden, blasting, and transporting the broken ore to a mill for processing. The cost of overburden removal is a major factor in talc mining, and waste rock to ore ratios of 40 to 1 are not uncommon. Drilling and blasting are carefully monitored to minimize costs, while being consistent with adequate fracturing of the ore. The production of steatite talc blocks used for sculpturing necessitates a minimum of blasting. In poorly indurated areas, backhoes may be adequate to rip the talc ore loose.

Open pit mining becomes uneconomical when the waste rock to ore ratio becomes too large, so that underground mining becomes necessary. Room-and-pillar and shrinkage stoping methods are used to mine talc underground. Room-and-pillar mining is used on flat or gently dipping ores where, as the ore body is mined, pillars of ore are left in a regular pattern to support the roof of the mine. Shrinkage stoping is used on steeply dipping ore bodies, where tunnels are driven into the base of the ore; drilling and blasting proceed upward into the orebody. Production is only a few tons per hour by either method.

In talc mining operations, the slipperiness of the talc ore can pose some unusual problems. Slip-reducing tires or chains may be used on mechanical loaders and haulers, and haulage slopes generally have gentle gradients. When mining underground, extensive cribbing and timbering may be required to support the rock (27).

Talc in Canada is produced at four open pits, two in Quebec and two in Ontario, and at two underground mines, one in Quebec and one in Ontario.

Processing

Beneficiation of talc can involve both pre-concentration and conventional milling. Pre-concentration of talc is usually employed when the talc is fairly white and the waste relatively dark. Selective mining and optical sorting are used to separate and reject the darker waste rock to produce a partially concentrated talc ore for further beneficiation.

Conventional milling includes a variety of grinding and beneficiation stages. Hammer mills and jaw crushers are used for primary size reduction, and roller mills are commonly used to produce fine-ground products for use as fillers or extenders in paint, plastic, rubber or asphalt compositions. When used in conjunction with air classifiers, roller mills can be used to grind talc to an approximate mean particle size of 5 to 10 μm. Colour is often a critical factor, so that ceramic-lined pebble mills are in common use. Talc is very soft and reasonable grinding rates can be achieved by using ceramic grinding media. The grinding

mills are sometimes equipped with oil or gas-combustion chambers to permit simultaneous grinding and drying of the ore, and are frequently used in closed circuit with air separators (27). Fluid-energy mills or pulverizing mills are usually used for ultrafine grinding of talc ore. Air pressure, moisture content, and temperature are carefully controlled to optimize the process (34).

The production of paper-grade or cosmetic-grade talc is usually only possible by flotation. The talc ore is ground to a size sufficient for liberation from accompanying gangue minerals, and floated at natural pH, usually 9.0, using an alcohol frother such as Dowfroth 250 or methyl-iso butyl carbinol. The process is usually very selective and multi-stage cleaning produces high grades of >95%. Sodium silicate is sometimes used as a slime dispersant or quartz depressant. Calcium hypochlorite is used for destroying bacteria when producing cosmetic-grade talc. Magnetic separation may be employed either before or after flotation to separate pyrrhotite and iron oxide minerals.

Following flotation, the talc concentrate is dried in a flash dryer and further ground in jet or vertical shaft-pulverizing mills.

Flow diagrams for two wet processing mills, Bakertalc Inc., Highwater, Quebec, and Steetley Talc, Timmins, Ontario, are shown in Figures 2 and 3, respectively.

Current Activity and Interest (20)

Quebec

Bakertalc Inc., Quebec, mines talc from an underground deposit near South Bolton in southern Quebec for processing at Highwater, 16 km south of the mine site. Products

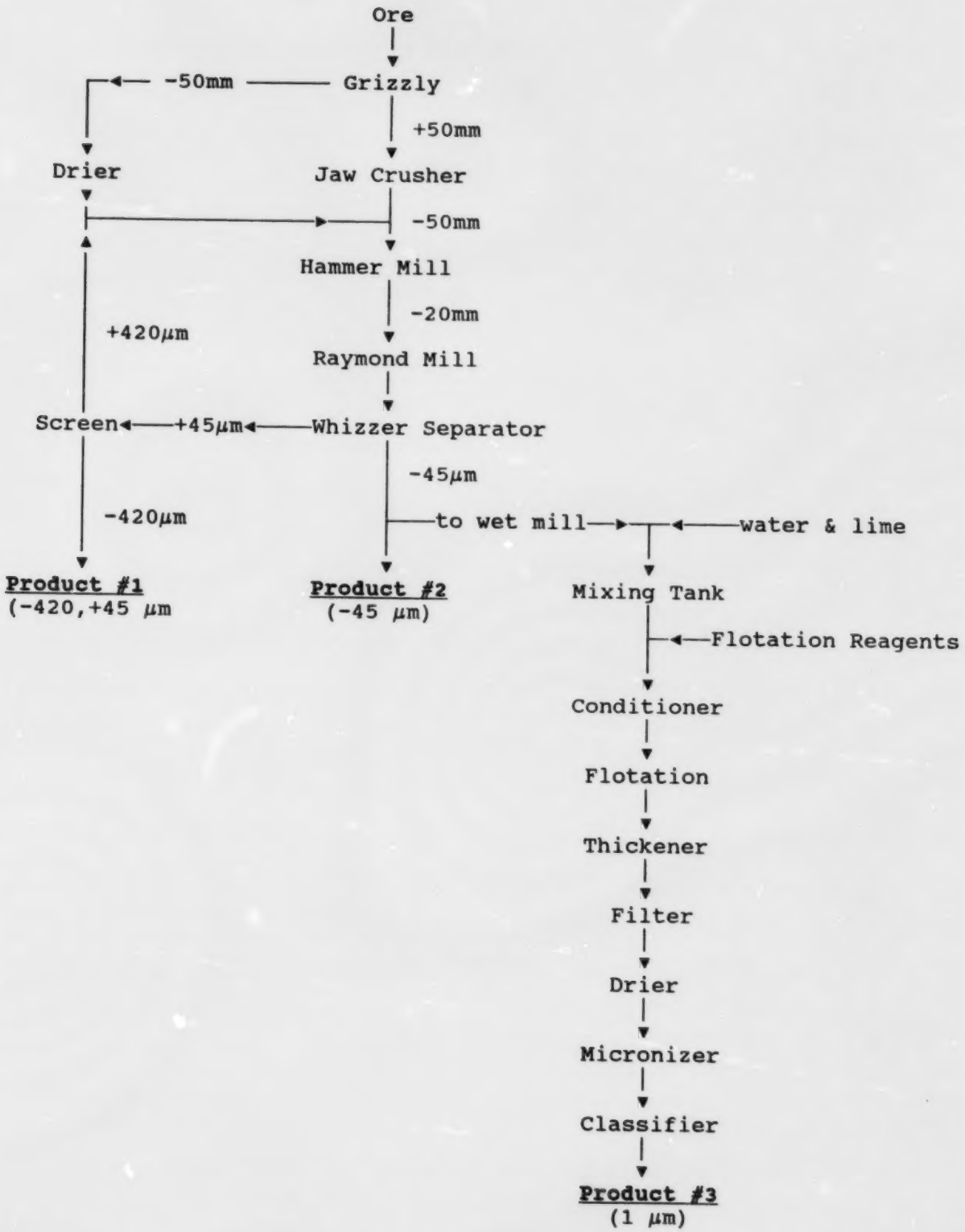

Fig. 2 - Flow diagram for Bakertalc Inc., Highwater, Quebec

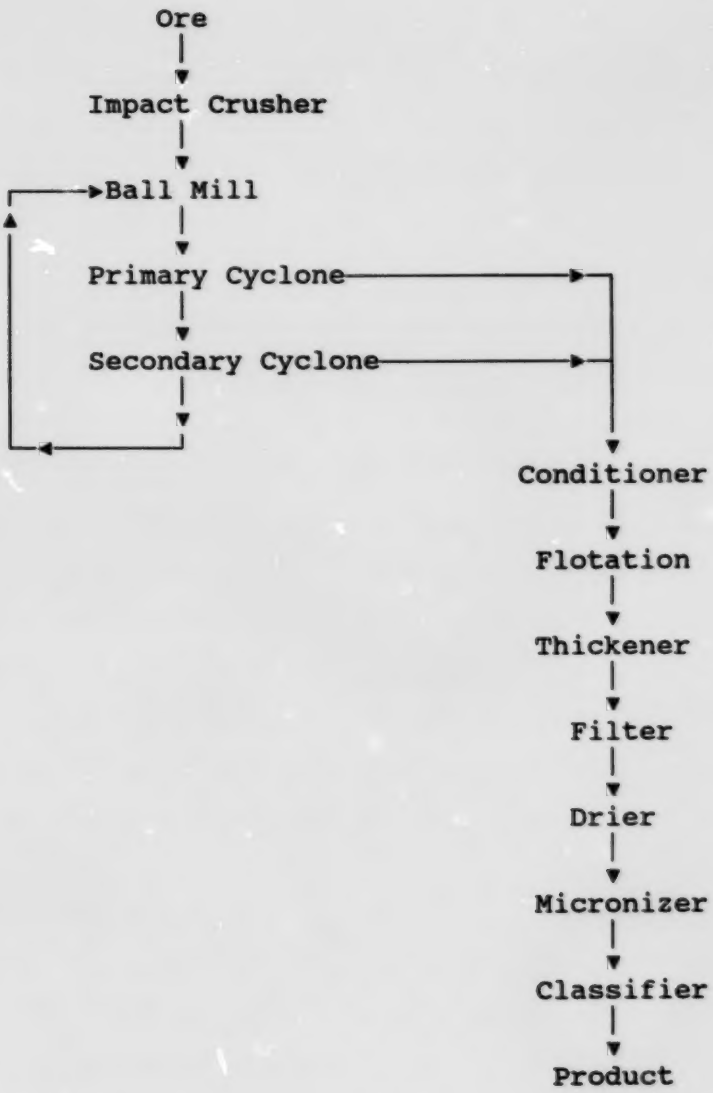

Fig. 3 - Flow diagram for Steetley Talc (Talc de Luzenac SA), Timmins, Ontario

include a dry-milled talc for use as a filler in paint and plastics, and a higher-purity flotation concentrate for use by the paper industry; total product capacity is about 18,000 tpa.

A second producer, Luzenac Inc., quarries two talc deposits near St. Pierre de Broughton. The mined ore is processed by dry milling to produce 50,000 tpa ground talc for use as a filler in joint cement and auto-body filling compounds, and as a dusting agent for asphalt roofing and rubber products. Talc-carbonate and talc-chlorite products are also produced for use as fillers in paint and plastics, and in floor tile and linoleum.

Recent developments include the rehabilitation of a former copper mine near Thetford Mines by International Larder Minerals Inc., for the recovery of ore-associated talc, and the development of a high-grade talc deposit between Leeds Station and East Broughton, by Carey Canada Inc. A 40,000 tpa processing plant is under construction at the Thetford Mines' site. The plant will supply ground talc for use in paint, roofing products, rubber and ceramics; estimated reserves of talc are 4Mt. A diamond drill program at the Leeds Station deposit indicated ore reserves of 8Mt grading 70 to 80% talc. Processing studies, which included flotation and grinding to 2 μm, showed recoveries of 85 to 90%; further diamond drilling is planned.

Ontario

Canada Talc Limited, a wholly owned subsidiary of Barmin Inc., of Waterdown, Ontario, operates an open pit and an underground mine near Madoc. The talc is of exceptional whiteness, but may contain accessory minerals such as mica, prismatic tremolite and sulphides. The ore is dry ground and classified to produce talc for various markets including paint, plastics and rubber. The processing plant has a capacity of 15,000 tpa. A larger plant built by Canada Talc in 1984 at Marmora, 20 km from Madoc, has a capacity of 40,000 tpa. An associated company, Easton Minerals Limited, is planning to construct a new processing plant at Northbrook. This plant will produce a very finely ground talc for use in specialty plastics and paper.

Talcs de Luzenac SA, the world's largest individual talc producer with operations in France, Spain and North America, recently acquired the Steetley Talc open-pit mine in Penhorwood twp., 70 km southwest of Timmins, and the micronizing plant at Timmins. Talcs de Luzenac SA will continue to operate both the mine and processing plant. The ore is ground, sized and beneficiated by flotation to produce cosmetic-grade talc. A lower grade product is also produced for use as a filler and extender in paint, paper, plastics and rubber, and for pitch control in paper manufacture. The plant capacity is about 60,000 tpa.

British Columbia

Pacific Talc Ltd. of Surrey is investigating an interesting talc deposit located 17 km northwest of the community of Boston Bar in southwestern British Columbia (35). The deposit has an exposed strike length of 500 m, a width varying from 10 to 50 m, and a depth of 60 m or more. The ore is an admixture of 60% talc and 30% magnesite, with 3 to 8% chlorite, 0.5 to 2% carbonate, and 6% iron oxide. Reserves are estimated at 1 Mt with an additional 6 to 9 Mt probable and inferred. Studies by Wyman (36) and others (37) show that the talc can be readily liberated and concentrated by flotation. Pacific Talc Ltd. is studying the feasibility of producing a modified talc in slurry form for sale to the pulp and paper industry.

Trifco Minerals Ltd., of Coquitlam, is investigating a talc occurrence in the Sovereign Creek area, 35 km southeast of Quesnel; four occurrences, identified as Dodo Creek, Creeks 1 and 2, Creek 3, and Swift River Forest Road, were sampled. The Dodo Creek deposit contains up to 450,000 t grading 45 to 90% talc; large pieces of float sampled in Creeks 1, 2 and 3 contained 80 to 90% talc; and the talc-carbonate schist occurring at Swift River contained up to 85% talc (38). Two samples of ore from this area were recently evaluated by Ortech International (39), and results are summarized in Appendix 2; further work is planned on these deposits.

Production and Trade

Available trade statistics for talc and pyrophyllite for 1989/90 are reported in Table 6. Production (shipments) statistics are not reported, there being only two producers of talc in each of Quebec and Ontario, and only one producer of pyrophyllite, in Newfoundland. Total shipments of talc and pyrophyllite in 1989 were 144,828 t valued at $15.1 M. Exports of talc for 1989, the latest year for which complete data is available, were largely to the United States and amounted to 43,740 t valued at about $8.6 M. Imports of talc for 1989, again mostly from the United States, amounted to 48,148 t with a value of $8.7 M. The reported consumption of talc in 1989, 70,025 t, was mostly in pulp and paper and asphalt roofing products.

The bulk of Newfoundland's pyrophyllite production was exported.

PYROPHYLLITE

Mineralogy and Geology

Pyrophyllite is a hydrous aluminum silicate with a theoretical chemical formula of $Al_2Si_4O_{10}(OH)_2$. Pyrophyllite is the aluminum analogue of talc and has many similar physical properties, although it is slightly harder and does not flux as easily when fired. Commercial grades of pyrophyllite rarely approach the theoretical composition of the pure mineral because of the presence of associated minerals (2). Chemical analyses of some commercial grades of pyrophyllite are reported in Table 7.

Table 6 - Canada: talc, steatite and pyrophyllite shipments, trade, 1989-90, and consumption, 1987-89

	1989		1990p	
	(tonnes)	($000)	(tonnes)	($000)
Shipments				
Talc and steatite				
Ontario[1]	n.a.	n.a.	n.a.	n.a.
Quebec[2]	n.a.	n.a.	n.a.	n.a.
Pyrophyllite				
Newfoundland	n.a.	n.a.	n.a.	n.a.
Total Shipments	**144 828**	**15 108**	**137 290**	**15 365**
Imports				
Natural steatite, not crushed/powdered				
United States	76	54	129	86
Other Countries (Brazil, China and Sweden)	56	40	220	38
Total	**132**	**94**	**349**	**124**
Talc, not crushed, not powdered				
United States	3 517	353	3 349	370
Other Countries (China and France)	40	20	10	7
Total	**3 557**	**373**	**3 359**	**377**
Talc of particle size not exceeding 20 microns, crushed or powdered				
United States	24 869	4 909	24 429	4 850
Other Countries (Japan, United Kingdom & USSR)	7	4	29	18
Total	**248 876**	**4 913**	**24 458**	**4 868**
Other natural talc, crushed or powdered				
United States	19 500	3 293	15 344	2 570
Other Countries (United Kingdom, Netherlands)	83	13	466	91
Total	**19 583**	**3 306**	**15 810**	**2 661**
Pyrophyllite				
United States	935	73	1004	84
Total	**935**	**73**	**1004**	**84**

Table 6 (cont'd)

	1989		1990p	
	(tonnes)	($000)	(tonnes)	($000)
Exports				
Natural talc, not crushed, not powdered				
West Germany	-	854	74	16
United States	2 950	-	37	11
Total	**2 950**	**854**	**111**	**27**
Natural talc, crushed or powdered				
United States	39 864	7 389	39 734	7 522
West Germany	926	332	274	95
United Kingdom				
Total	**40 790**	**7 721**	**40 008**	**7 617**

	1987	1988	1989p
	(tonnes)	(tonnes)	(tonnes)
Reported consumption[3] (ground talc, available data)			
Pulp and paper and paper products	24 249	28 689	27 436
Asphalt roofing products	20 837	21 410	21 989
Paint, varnish	5 547	6 708	6 538
Ceramic products	3 000	4 155	4 118
Rubber products	2 097	2 786	2 308
Toilet preparations	1 438	1 398	1 550
Other products[4]	8 783	5 438	6 086
Total	**65 951**	**70 584**	**70 025**

Sources: **Statistics Canada**; Energy, Mines and Resources Canada.

1. Ground talc
2. Ground talc, soapstone, blocks and crayons
3. Reported from EMR survey on the consumption of nonmetallic minerals by Canadian manufacturing plants
4. Chemicals, fertilizers, gypsum products, refractory brick and other miscellaneous uses.

p = Preliminary
n.a. Not available

Table 7 - Chemical analyses of commercial grades of pyrophyllite (40,41)

	% Weight		
Oxide	1	2	3
SiO_2	65.8	65.9	69.4
Al_2O_3	28.2	26.4	26.0
Fe_2O_3	0.11	0.60	0.12
TiO_2	0.18	1.00	-
CaO	0.28	0.67	0.20
MgO	0.01	0.17	-
K_2O	0.04	0.33	-
Na_2O	0.10	0.70	0.24
H_2O	4.95	4.26	4.50

1. High grade Pambula, Australia
2. Massive type, Turkey
3. North Carolina, U.S.A.

Pyrophyllite occurs in association with acid-volcanic rocks as a hydrothermal or metasomatic alteration of feldspars in rhyolites, dacites and andesites (41). Associated minerals include kaolinite, alunite, quartz, pericite, montmorillonite, diaspore, corundum and, less commonly, pyrite, chlorite, feldspar, hematite and magnetite (5). Cornish (42) divides pyrophyllite deposits into two distinct classes, hydrothermal and metamorphic, based on their mode of occurrence. Hydrothermal deposits are associated with acid-volcanic complexes and are the more common type. Metamorphic deposits are less common and occur as pyrophyllite schists associated with metamorphosed volcanics.

Pyrophyllite has a pearly lustre, greasy feel, and may be white to green, grey or brown in colour. Pyrophyllite possesses good cleavage, is chemically inert, is relatively soft with a hardness of 1 to 2 on the Moh scale, and has a specific gravity of 2.84.

Principal Occurrences

Pyrophyllite is not as common as talc, and known occurrences in Canada are essentially limited to three provinces: Newfoundland, Quebec and British Columbia. These are noted on the map, in Figure 1.

Newfoundland

The most important deposits of pyrophyllite occur on the Avalon Peninsula near the small town of Foxtrap, about 18 km west of St. John's. The pyrophyllite deposits, which occur in a narrow belt running south of the east side of Conception Bay and along the east side of the Precambrian Holyroad granite batholith, a major structure in the area, were recently documented by Guillet et al. (43). Three main deposits were identified: Fox Trap, Trout Pond and Dog Pond. These deposits occur as lenses of massive pyrophyllite associated with pyrophyllite-sericite-quartz schists, which have resulted from the hydrothermal metasomatism of rhyolitic volcanics in contact with the granite intrusive. The zone of alteration extends over a strike length of 7 km and encompasses all three deposits. The Trout Pond and Dog Pond deposits are, respectively, 3 and 6 km south of the main Fox Trap deposit.

Mining of pyrophyllite in the Fox Trap (Manuels) area has been carried on intermittently since the early 1900s, and more or less continuously since the mid 1950s by Newfoundland Minerals at its Oval Pit quarry. Reserves are relatively extensive and adequate for 40 years at the current rate of operation.

The Trout Pond and Dog Pond deposits have been drilled and sampled by Newfoundland Minerals. Reserves at the latter deposit are estimated at 36,000 t of pyrophyllite with intermixed sericite. The chemical and mineralogical compositions of selected samples from the three deposits are reported in Table 8.

Table 8 - Chemical and mineralogical analyses of selected pyrophyllite samples (43)

Oxide	Fox Trap			Trout Pond	Dog Pond	
	High grade	Shipping grade	Low grade		A	B
SiO_2	66.0	76.2	84.9	74.2	58.0	75.7
Al_2O_3	27.0	18.3	11.9	20.2	32.2	18.6
CaO	0.02	0.02	0.02	0.01	0.01	0.02
MgO	0.04	0.02	<0.01	0.03	0.05	0.05
Na_2O	0.15	0.05	<0.01	0.02	0.14	0.05
K_2O	0.81	0.55	0.37	0.63	4.21	1.30
Fe_2O_3	0.08	0.09	0.06	0.12	0.10	0.09
MnO	0.01	0.01	0.01	0.01	0.01	0.01
TiO_2	0.37	0.24	0.16	0.28	0.37	0.24
P_2O_5	0.03	0.02	0.04	0.03	0.04	0.03
LOI	4.93	3.47	2.47	3.85	5.00	3.47
Minerals*						
Major	py	py	qu	py	py	qu
	-	qu	py	qu	ser	py
Minor	qu	-	-	-	-	ser
Trace	ser	ser	-	ser	qu	-

*py = pyrophyllite ; qu = quartz ; ser = sericite

Quebec

Pyrophyllite occurring in northwestern Quebec in Carpentier Township, Abitibi region, in an area 10 km northeast of Barraute, has been described in some detail (44). Diamond drilling in the mid-1960s outlined two pyrophyllite deposits at the northern and southern extremities of the northwest/southeast trending pyrophyllite schist shear zone. The North deposit consists of a pyrophyllite zone enclosed by a pinite zone, and a pyrophyllite- chloritoid-alumina zone. Core sample analyses indicated 40% pyrophyllite over a 40 m length with the remainder chiefly consisting of quartz. The South deposit consists of a 30 m thick zone with a combined pyrophyllite-pinite-paragonite content of 65%.

Reserves of high-grade pyrophyllite, based on the mid-1960s drill programme, were estimated at 2 Mt. Laboratory studies demonstrated that air separation could be used to separate quartz, the chief contaminant, from finely ground samples. Dry and wet magnetic separation were successfully employed to remove iron, a reduction of 90% being reported.

Spence (11), referencing an early report (45) by the Geological Survey of Canada, notes occurrences of pyrophyllite in Brome and Beauce counties in the southeastern part of the province, as follows:

> "Pyrophyllite occurs near Stanstead Township, Brome county, on the east shore of Lake Memphremagog in a 50 m wide belt enclosed in chloritic slates. The material is described as partly granular and almost pure, and partly schistose with considerable quartz. The massive type has a light yellow colour and is translucent and unctuous, resembling steatite. Similar material occurs near St. Nicholas on the south shore of the St. Lawrence River, about 19 km west of Levis, and near the Famine River, in the parish of St. Francis, Beauce County, southeast of the above.
>
> At the former locality the pyrophyllite is described as variously granular, massive, or schistose in texture, with a shining, waxy lustre, and of a greenish colour, resembling steatite, and forming thin layers up to 25 mm in thickness in shales and sandstones close to a body of intrusive trap rock. The St. Francis material is described as being of similar character and forming a thin bed in clay slate."

Reported analyses of material from the Stanstead, St. Nicholas and St. Francis localities are tabulated in Table 9.

Table 9 - Analyses of pyrophyllite samples in Brome and Beauce Counties (45)

Oxide	Sample Number			
	1	2	3	4
SiO_2	48.42	48.50	50.50	50.30
Fe_2O_3	4.50	5.67	Trace	Trace
Al_2O_3	27.60	27.50	33.40	32.60
CaO	2.80	1.30	Trace	-
MgO	1.80	2.24	1.00	1.20
K_2O	5.02	5.30	8.10	-
Na_2O	2.78	1.91	0.63	-
H_2O	6.88	7.40	5.36	6.50
Total	**99.80**	**99.82**	**98.99**	**90.60**

1. Pyrophyllite (agalmatolite) from St. Nicholas.
2. Pyrophyllite (agalmatolite) from St. Nicholas.
3. Agalmatolite from St. Francis.
4. Agalmatolite from Stanstead Township.

British Columbia

Spence (11) notes pyrophyllite and associated alunite as occurring in the northwestern portion of Kyuguot Sound, a large inlet on the west coast of northern Vancouver Island. Two deposits are reported on the north side and two on the south side of a small peninsula between Kokshittle Arm and Easy Cove.

Spence quotes from a comprehensive description of these deposits by Clapp (46), who examined the area in 1913, as follows:

> "The rocks with which the pyrophyllite and alunite deposits are associated are chiefly volcanics of Triassic and Lower Jurassic age, consisting of porphyritic and fragmental andesites and dacites. The pyrophyllite and alunite occur in separate and well defined masses as replacements of volcanic rocks along their contacts with intrusive diorite and andesite.

The pyrophyllite is mainly of compact, massive type, and occurs in bodies of pyrophyllite-quartz rock, containing minor sericite with quartz forming 20 to 50% of the rock. Quartz-sericite rock is the most abundant type. Quartz-pyrophyllite rock is less common and appears to be developed chiefly on the south and north sides of a small peninsula between Easy Cove and Kokshittle Arm. It is also exposed over a small area in the south shore of Easy Cove.

The pyrophyllite rock is described as dense, with a pronounced greasy or soapy feel, and is readily crushed to a fine, smooth powder. It consists essentially of quartz and pyrophyllite, with small amounts of accessory sericite, pyrite and kaolin. The quartz is very fine grained, while the pyrophyllite is in the form of very fine, microscopic flakes.

Clapp says little about the width or extent of the pyrophyllite-quartz bodies, but estimates the amount of material in the two peninsula deposits to contain about 500,000 t."

The grade of the rock is not noted accurately beyond estimating that the quartz content was between 20 and 50%. Analyses of two samples of pyrophyllite and one of quartz-sericite rock from the peninsula deposits are reported in Table 10.

Table 10 - Pyrophyllite and Quartz-Sericite Analyses (46)

Oxide	Sample Number		
	1	2	3
SiO_2	81.94	71.88	87.80
Al_2O_3	15.29	23.56	9.08
Fe_2O_3	0.11	0.14	0.40
Na_2O	0.40	0.36	0.02
K_2O	0.50	0.43	1.70
H_2O	2.40	3.24	1.04
Total	**100.64**	**99.61**	**100.04**

1. Pink to white quartz-pyrophyllite rock, analyzing about 42% pyrophyllite and 50% quartz.
2. White to grey quartz-pyrophyllite rock, analyzing about 71% pyrophyllite and 20% quartz.
3. Cherty quartz-sericite rock.

There was some exploratory development of these deposits in the early 1900s but there is none at present.

MacLean (5) provides additional information on the Kyuquot Sound pyrophyllite deposits and notes three additional occurrences: Island Copper on Vancouver Island, approximately 75 km north of Kyuquot Sound; Riverside, about 16 km east of Ashcroft; and Pyro Group, about 5 km northwest of Princeton. The Island Copper deposit occurs in an altered breccia zone up to 150 m wide by 1000 m long, and consists of massive greyish tan pyrophyllite with associated quartz, kaolin and blue dumortierite. The pyrophyllite at the Riverside deposit occurs with quartz, calcite and minor pyrite as wallrock alteration along a sheer zone in a rhyolite porphyry. An 82 t shipment of ore from this deposit was evaluated for use as a filler and in ceramic application at a processing facility at Lethbridge, Alberta, in 1950; however, there have been no further developments. The Pyro Group deposit is a mixture of quartz and pyrophyllite. Pyrophyllite from this property has been used by Clayburn Industries Limited of Abbotsford since 1972 for the manufacture of acid refractories.

Uses and Specifications

Pyrophyllite, being physically similar to talc, may substitute for talc in a number of applications. Pyrophyllite may also be used in refractory applications because, unlike talc, pyrophyllite does not flux when heated. Cornish (42) subdivides uses into several categories as follows:

Contact Refractories

The Japanese steel industry successfully used pyrophyllite to make ladle lining refractories in the late 1960s. Subsequent development testwork in Australia has confirmed that linings made from pyrophyllite and zircon/pyrophyllite increased ladle life significantly. The ladle lining life could be improved by 100% for pyrophyllite bricks and by 450% for zircon/ pyrophyllite bricks compared to bloating clay bricks. This was achieved at 75% of the cost

per tonne of steel produced compared with the cost of production using the traditional bloating brick. Pyrophyllite, as the sole constituent, is used for lining the inner sections of ladles, tundish and cupola. In the second variety, pyrophyllite is used in combination with other materials, notably chamotte, zircon and silicon carbide. This multi-component composition is also used in monolithics (47).

Pyrophyllite has a distinct advantage over talc in that at high temperatures it swells and melts to form a glassy surficial coating on the brick which helps to prevent ingress of molten steel to the interior. The principal disadvantage is its relatively low melting point which can adversely affect the number of heating cycles obtained when used in high temperature regimes.

Specifications for ladle bricks stipulate that pyrophyllite with a low alkali content, $<0.5\%$, should be used. The product grade is determined generally by the Al_2O_3 content which is usually between 14 and 20% (42). A typical product specification is reported in Table 11.

Kiln Furniture

Pyrophyllite is used as a grog for kiln furniture shapes such as slabs, saggers, blocks and pins. The pyrophyllite prolongs the life of the furniture and lowers maintenance costs. The extended life is attributable to excellent heat shock resistance, low coefficient of thermal expansion, low shrinkage and high resistance to deformation under load, and a moderate to high PCE (pyrometric cone equivalent) of 30 to 32.

Specifications for this application stipulate that Al_2O_3 should be between 18 and 20% and total alkalis approximately 1%. A typical product analysis is reported in Table 12.

Table 11 - Specifications for contact-refractory pyrophyllite (42)

Oxide	% Weight
Al_2O_3	15.80
SiO_2	78.50
Fe_2O_3	0.38
Na_2O	0.11
K_2O	0.24
CaO	0.30
MgO	0.12
TiO_2	0.39
LOI	3.90
Size range	-15 mm) -10 mm) $\pm$600 μm -1.7 mm) and fines
Specific gravity	2.65
PCE	28 to 30
Thermal properties	Dilatometric curves of fired pyrophyllite PCE* Cone 31

*Pyrometric Cone Equivalent

Table 12 - Specifications for tunnel kiln-furniture pyrophyllite (42)

Oxide	% Weight
Al_2O_3	20.60
SiO_2	73.90
Fe_2O_3	0.45
Na_2O	0.12
K_2O	0.44
LOI	4.30
Specific gravity	2.65
Size range	-1.7 mm + fines -600 μm + fines
PCE	30 to 32
Thermal properties	Dilatometric curves of fired pyrophyllite PCE Cone 31

Refractory Mortars

Phyrophyllite is used in the manufacture of refractory mortars because it imparts satisfactory plasticity and low drying and firing shrinkages when compared with clay-based compositions. A typical product analysis for this application is reported in Table 13.

Table 13 - Specifications for refractory-mortar pyrophyllite (42)

Oxide	% Weight
Al_2O_3	20.60
SiO_2	73.90
Fe_2O_3	0.45
Na_2O	0.12
K_2O	0.44
PCE	28 to 32
Size	-1.7 mm + fines

Whiteware

Pyrophyllite is used in the ceramics industry to manufacture floor and wall tile, sanitary ware, crockery and electrical porcelain. Pyrophyllite lowers the firing temperature, suppresses deformation and cracking, increases whiteness, lowers firing shrinkage and improves thermal shock resistance. Specifications for this application are reported in Table 14.

White Cement

Pyrophyllite with a low iron content, when used as a component in the manufacture of white cement, assists in maintaining high whiteness levels in excess of 90%. Specifications for this

application are generally less exact, however, Al_2O_3 should be between 15 and 20% and Fe_2O_3 between 10 and 20% (42).

Table 14 - Specifications for whiteware pyrophyllite (42)

Oxide	% Weight
Al_2O_3	28.20
SiO_2	65.80
Fe_2O_3	0.11
Na_2O	0.10
K_2O	0.04
CaO	0.01
MgO	0.01
TiO_2	0.18
LOI	5.10
PCE	16 to 33
Specific gravity	2.80
Size analysis:	
-150 + 75 μm	Trace
-75 + 50 μm	0.30
-50 μm	99.70
Thermal properties	Dilatometric curves of fired pyrophyllite PCE cone 33

Mineral Fillers

Pyrophyllite, when finely ground and quartz free, may be substituted for talc in certain filler applications including rubber, plastics, paints, cosmetics and jointing compounds. Paint is currently the largest filler market for pyrophyllite (41). Specifications for mineral filler applications are reported in Table 15.

Table 15 - Specifications for mineral filler applications (42)

Oxide	% Weight
Al_2O_3	28.20
SiO_2	65.80
Fe_2O_3	0.22
Na_2O	0.10
K_2O	0.04
CaO	0.28
MgO	0.01
TiO_2	0.18
LOI	5.10
Brightness	80 to 90
Water absorption	50%
Specific gravity	2.74
Size range	
-150 + 75 μm	Trace
-75 + 50 μm	0.30
-50 μm	99.70

Miscellaneous

Calcined pyrophyllite is used in road surface aggregate in applications requiring paint markings, e.g., pedestrian crossings. The advantages of using calcined pyrophyllite are high anti-skid properties, high-polished stone value (PSV), high-aggregate impact value (AIV), and high-luminance factor (42). A major expanding use for pyrophyllite is as a carrier in the insecticide industry (41). An interesting new and successful use is the manufacture of ceramic glazes (42).

The reaction vessel used for the manufacture of synthetic diamonds is usually constructed of pyrophyllite. Pyrophyllite is used because it can be easily machined to accurate specifications and it remains inert during the reaction. A harder pyrophyllite from South Africa,

'wonderstone', is preferred for this application because it also acts as an excellent electrical insulator and is a perfect sealant. Other minor uses for pyrophyllite include rice polishing, art sculptures, foundry facing, stucco and asphalt filler (41).

Current Activity and Interest

Newfoundland Minerals, a division of Armstrong World Industries Canada Ltd., is the only current producer of pyrophyllite in Canada. The company obtains pyrophyllite by open-pit methods from a deposit near Manuels, about 18 km west of St. John's, Newfoundland. The ore is crushed to about 100 mm at the mine site and trucked about 5 km to shipping facilities at Fox Trap, where it is stockpiled in separate piles based on grade. The ore, a pyrophyllite-quartz product containing minor sericite, is blended to company specifications, 17.5% R_2O_3 (mostly alumina) and 0.65% alkalies, for shipment to ceramic floor and wall tile plants at Lansdale, Pennsylvania, and Jackson, Mississippi (43). Reserves are reported to be adequate for 40 years at current levels of production. Small tonnages of lower grade pyrophyllite have been used locally in the manufacture of joint cement for gypsum wallboard, and as a filler in paint and other products. Trial shipments of pyrophyllite to Germany for similar applications are reported.

A study, conducted in 1987 under the Canada/Newfoundland Mineral Development Agreement, examined the possibility of improving the quality of pyrophyllite ore from the Manuel's area deposit to supply larger markets and identified potential additional markets (43). The results of this study are summarized in Appendix 4.

Production and Trade

Available trade statistics for pyrophyllite are reported with those for talc in Table 6. There is only one major producer, so that production is not reported; as previously noted, the bulk of production is exported to the United States. Imports of pyrophyllite from the United States in 1989 amounted to 935 t valued at $73,000.

CANMET STUDIES

Background

Twenty-eight CANMET talc and soapstone beneficiation studies (49-80), and eight by other organizations (39,81-87) were reviewed. Five CANMET studies of pyrophyllite beneficiation were reviewed (88-92), and one by another organization (93). Summaries of CANMET talc and soapstone studies are presented in Appendix 1, and the studies by other organizations in Appendix 2. Summaries of CANMET pyrophyllite studies are presented in Appendix 3, and of the one study by another organization in Appendix 4.

The summary of each study includes, if known, the original sample weight, head analysis, mineralogy, beneficiation methods, beneficiation product sizes, concentrate grades and recoveries, and remarks or observations of particular interest. The original sample weight is indicative of the scale of investigation, whether bench, laboratory, semi-pilot plant or pilot plant. The head analyses provide data concerning the mineral content and whether the sample originates from a high or low-grade deposit. Mineralogical information not only identifies major and minor minerals, but also provides data regarding association between minerals and host rocks. The liberation size in many cases is either not known or not stated; the beneficiation product size is quoted since, by inference, product size under optimum test conditions usually equates to liberation size. Beneficiation methods are important as a guide for future studies of ores with similar mineral assemblages, and concentrate grade and recovery figures provide an indication of how efficient the beneficiation methods were in achieving a specification product. Additional data regarding flotation parameter and reagent concentration are also reported. Studies common to a particular deposit, when possible, are grouped together for continuity and convenience of reference.

The twenty-eight talc and soapstone studies and five pyrophyllite studies were conducted by CANMET and its predecessor, Mines Branch, between 1928 and 1987. The majority of talc and soapstone studies were conducted on samples from Quebec and Ontario; most pyrophyllite studies, with one exception, were conducted on samples from Newfoundland.

A summary of process data for talc and soapstone beneficiation studies is reported in Table 16, and of analytical data in Table 17. Pyrophyllite beneficiation process data is similarly reported in Table 18, and analytical data in Table 19.

Scale

The feed weight for most talc and soapstone studies was less than 270 kg; six studies (49,58,59,62,82,84) were conducted on samples weighing 1t or more. Similarly, the feed weight for most pyrophyllite studies was about 225 kg; one study was conducted on a sample weighing 445 kg (88).

Head Analyses

The analyses of talc samples varied widely, from 23% talc in a magnesite ore from Deloro, Ontario (72), to 95% talc in a talcose sample from Silver Moon, British Columbia (87). The analysis for most ores was between 45 and 60% talc.

Pyrophyllite samples, with one exception, were all from Manuels, Newfoundland. The content was almost as variable as that of the talc samples, from 40 to 98% pyrophyllite (91,88). The range of analysis for most samples was from 40 to 80% pyrophyllite.

Mineralogy

Talc

Talc usually occurs as a secondary mineral resulting from the hydration of magnesium-bearing rocks such as peridotites, gabbros and dolomite. When talc is formed from peridotite (a mixture of magnesium-rich olivine and pyroxene), the process is referred to as serpentinization or steatization. Typically, chlorite is associated with this type of talc. When talc occurs in sedimentary deposits, the host rock is usually dolomite, which may also contain silica. Typically, tremolite occurs with this type of talc.

The various talc samples may be classified into these two types, i.e., magnesitic and dolomitic. The minerals associated with magnesitic talc were major magnesite, minor dolomite, and a range of iron-containing minerals including ferruginous chlorite, pyrrhotite, pyrite, limonite and magnetite. Miscellaneous minerals associated with magnesitic talc included ilmenite, quartz, amphibole and hornblende. Dolomitic talc was typically composed of major dolomite and a range of minerals including quartz, tremolite, serpentine, feldspar, muscovite and various iron oxide minerals. Dolomite may also occur as ferro-dolomite and breunerite (77).

Pyrophyllite

Pyrophyllite was associated usually with major quartz. The range of associated silicate minerals occurring in minor amounts included zoisite, clinozoisite, muscovite, paragonite and kaolinite.

Table 16 - Summary of process data for talc and soapstone beneficiation studies

Deposit location	Lot No.	Sample wt (kg)	Process method	Ref. No.
Quebec				
Robertsonville	1	1.6t	crushing, grinding, air classification	49
Broughton	1	n.s.	grinding, flotation	50
Brome Co.	1	60	grinding, magnetic separation, flotation	51
East Malartic	1	105	grinding, flotation	52
	2	40	grinding, magnetic separation, flotation	52
Highwater	1	30	crushing, screening	53
Highwater	1	50	flotation, magnetic separation	54,55
	2	15	grinding, flotation	54,55
Highwater	-	2	plant sampling survey	56,57
Highwater	1	5 t	magnetic separation, flotation, spiral concentration, acid leaching	58,59
	2	5 t	grinding, flotation, magnetic separation	58,59
Ontario				
Madoc	1	90	grinding, screening, air classification, wet tabling, flotation	60
Madoc	1	n.s.	grinding, flotation	61
	2	n.s.	grinding, flotation	61
Madoc	1	1 t	flotation	62
Madoc	1	90	crushing, grinding, flotation	64
Madoc	1	75	screening, photometric sorting	65
Madoc	1	n.s.	electronic ore sorting, differential grinding, flotation	66,67
Madoc	1	60	grinding, flotation, magnetic separation, acid leaching	68
Madoc	1	n.s.	crushing, wet and dry screening, grinding, flotation	83
Madoc	3	n.s.	crushing, wet and dry screening, grinding, flotation	83
Deloro	1	750	crushing, dry grinding, flotation	69
Deloro	1	n.s.	crushing, dry grinding, flotation	70
Deloro	1	100	crushing, dry grinding, flotation	71
Deloro	1	270	crushing, differential grinding, flotation, magnetic separation	72
Deloro	1	500	crushing, grinding, flotation, magnetic separation	81
Deloro	1	2 t	crushing, grinding, flotation with regrinding and reflotation	84
Grimsthorpe	1	4	grinding, flotation	73
Matheson	1	45	grinding, flotation, magnetic separation	74
Matheson	1	7 t	crushing, grinding, classification, flotation	82
Adams Twp.	1	n.s.	grinding, flotation, magnetic separation	75
Tweed	1	7	crushing, wet grinding, flotation, magnetic separation	85
	2	7	crushing, wet grinding, flotation, magnetic separation	85
	3	7	crushing, wet grinding, flotation, magnetic separation	85
Manitoba				
Cranberry Portage	1	3	crushing, desliming, flotation	76
Cranberry Portage	1	60	grinding, flotation	77
	2	55	grinding, flotation	77
British Columbia				
Silver Moon	1	11	firing, paint pigment evaluation	78
Nahatlatch	1	10	differential grinding, flotation	79
RiverChu-Chua	1	200 g	too small for detailed evaluation	80
Quesnel	1	25	crushing, dry grinding, flotation, wet magnetic separation	39
	2	25	crushing, dry grinding, flotation, wet magnetic separation	39

Table 17 - Summary of analytical data for talc and soapstone beneficiation studies

Deposit location	Lot No.	Head analysis			Product analysis, %			Rec %	Ref. No.
		Talc[1]	Fe[2]	CaO[3]	Talc	Fe	CaO		
Quebec									
Broughton		n.s.	4.03	4.50	n.s.	0.39	<1.0	-	50
Brome Co.	1	82.9	3.80	-	85.0[4]	3.40	-	-	51
East Malartic	1	45.0	8.45[5]	n.s.	90.0[4]	0.20	0	57.4	52
	2	45.0	11.84[5]	n.s.	85.0[4]	0.33	0.25	53.8	52
Highwater	1	62.6	4.35	n.s.	96.0	trace	0.33	66.0	54,55
	2	55.6	n.s.	n.s.	77.5	trace	trace	93.9	54,55
Highwater	1	61.4	5.23	n.s.	97.2	trace	trace	57.9	58,59
	2	62.2	5.07	n.s.	97.0	trace	trace	75.9	58,59
Ontario									
Madoc	1	51.8	n.s.	5.70	90.0[4]	n.s.	0.32	n.s.	60
Madoc	1	85.0[4]	n.s.	1.79	90.0[4]	n.s.	0.35	51.8	61
	2	45.0[4]	n.s.	10.34	90.0[4]	n.s.	0.62	23.0	61
Madoc	1	50.0[4]	n.s.	8.38	90.0[4]	n.s.	1.76	n.s.	62
Madoc	1	50.0	-	15.2[5]	97.2	-	n.s.	64.1	64
Madoc	1	50.0	-	n.s.	88.0	-	n.s.	46.9	66,67
Madoc	1	52.0	1.14	19.46	90.0	0.39	0.42	n.s.	68
Madoc	1	50.0	n.s.	12.2[5]	90.0[4]	n.s.	1.02	49.7	83
	3	40.0	n.s.	15.2[5]	90.0[4]	n.s.	1.90	39.6	83
Deloro	1	23.0	0.80[5]	trace	96.9	0.18	trace	66.8	72
Deloro	1	35.0[5]	4.19	-	95.0	0.37	-	n.s.	81
Deloro	1	23.0	n.s.	-	95.6	n.s.	-	71.9	84
Grimsthorpe	1	56.3	2.18	n.s.	92.4	n.s.	n.s.	38.5	73
Matheson	1	55.0	n.s.	-	90.0[4]	n.s.	-	77.5	74
Matheson	1	45.0	2.17[5]	-	92.9	n.s.	-	n.s.	82
Tweed	1	55.0[4]	4.19	9.72	90.0	1.75	0.88	30.0	85
	2	55.0[4]	4.19	10.90	90.0	1.75	1.38	20.0	85
	3	55.0[4]	5.24	6.60	93.0	3.14	0.79	40.0	85
Manitoba									
Cranberry Portage	1	43.0	3.49	-	n.s.	0.30	-	90.0	76
Cranberry Portage	1	39.0	0.96	17.9	n.s.	1.95	n.s.	56.9	77
	2	52.0	1.92	13.4	n.s.	2.02	n.s.	57.9	77
British Columbia									
Nahatlatch River	1	70.8	n.s.	97.8	n.s.	n.s.	n.s.	48.5	79
Quesnel	1	65.0[5]	6.08[5]	n.s.	n.s.	n.s.	n.s.	n.s.	39
	2	65.0[5]	6.08[5]	n.s.	n.s.	n.s.	n.s.	n.s.	39

[1]Analysis by either acid insoluble or loss on ignition
[2]Calculated from iron oxide analyses
[3]Total carbonates
[4]Estimated
[5]Estimated from mineralogical data

n.s. - not stated

Table 18 - Summary of process data for pyrophyllite beneficiation studies

Deposit location	Lot No.	Sample wt (kg)	Process method	Ref. No.
Newfoundland				
Manuels	1	220	dry grinding	88
	2	220	grinding, flotation	88
	3	445	grinding, flotation	88
Manuels	1	230	dry grinding, air classification, flotation	89
Manuels	1	n.s.	grinding, attrition, air classification, flotation	90
Manuels	1	220	dry grinding, flotation	91
	2	220	dry grinding, flotation	91
	3	45	not processed	91
British Columbia				
Semlin	1	130	sorting, screening, grinding	92

Table 19 - Summary of analytical data for pyrophyllite beneficiation studies

Deposit location	Lot No.	Head analysis, %		Product analysis, %			Rec %	Ref. No.
		Pyro*	Qtz*	Fe_2O_3	LOI	Al_2O_3		
Newfoundland								
Manuels	1	98	-	n.s.	-	-	n.s.	88
	2	80	-	0.002	-	-	64.0	88
	3	80	-	0.002	-	-	84.0	88
Manuels	1	62	38	-	3.43	-	62.0	89
Manuels	1	62	38	-	4.08	-	71.0	90
Manuels	1	40	50	-	-	20.43	64.5	91
	2	45	-	-	-	29.26	40.3	91

*Estimated pyrophyllite and quartz content from mineralogical data

Analysis

Talc

Talc, like many other silicate minerals, cannot be analyzed by a straightforward chemical element analysis procedure. There are several simple and relatively quick methods in use, principally acid insoluble, loss on ignition, carbon dioxide analysis and brightness determination. These methods are limited and can only be used for specific ores. Acid insoluble, for example, would only be accurate if talc were the only insoluble mineral (54,58). The LOI method similarly is restricted if chlorite is present, since chlorite disintegrates at temperatures normally employed for LOI determinations.

The more accurate methods are X-ray fluorescence of equivalent oxides, X-ray diffraction, and differential thermal analysis. Equivalent oxide determinations are only valid for virtually pure talc products, when the analysis values of Al_2O_3, for example, are so small that calculated analyses for chlorite, being equally small, would not significantly alter the pure talc anlaysis. Oxide analysis, however, cannot effectively determine the mineral analysis of a lower grade multi-mineral talc product, where many minerals may be present in substantial amounts, with oxides in common (68).

X-ray diffraction is based on comparing peaks with a standard talc. Analyses using this procedure are generally accurate, but if iron or chlorite form part of the talc crystal structure, variance is possible.

Differential thermal analysis is based on differing temperatures for loss on ignition of minerals usually associated with a talc ore. It is claimed that differential thermal analysis is suitable for Quebec talc ores (48). A talc sample is first heated to 840°C for 4.3 min, which allows conversion of chlorite, magnesite and calcite. A further heating for 15 min at 1000°C converts the talc. Talc content is then calculated from the difference in weight at the two temperatures divided by 4.18, which is the loss on ignition value for talc.

Pyrophyllite

The difficulties of representative talc analysis also apply to pyrophyllite, since each mineral is characterized by a hydrous silicate structure. Analysis methods for pyrophyllite are therefore similar to talc. The Al_2O_3 analysis had been used to determine pyrophyllite, but this method can be doubtful if zoisite, muscovite and other alumino-silicate minerals are present.

Flotation

Talc

The processing of talc for most samples basically involved only grinding, flotation, and magnetic separation of iron oxide minerals, usually from a beneficiated talc concentrate.

The grind size for most talc samples was fine, between 210 and 50 μm. Coarser grind sizes were reported up to 300 μm (72,75), and the coarsest size was 600 μm (79).

Flotation was the preferred concentration technique, since talc is naturally floatable, usually requiring only a frother to effect flotation. The frother generally employed was Pine Oil (terpineol) with additions of between 15 and 168 g/t. The range of frothers was later extended to include Dowfroth 250 (polypropylene glycol methyl ether), MIBC (methyl iso-butyl carbinol) and Aerofroth 70 (C_6 branch chain alcohol). Frother additions for these collectors were generally slightly less, between 15 and 94 g/t. A primary amine was used in some investigations (64,66,67,83), and collector concentrations were higher, between 125 and 300 g/t. A summary of collector and frother concentration data for talc flotation is reported in Table 20.

Table 20 - Summary of collector concentration data in g/t for talc flotation

Deposit location	Pine oil	Amine	Xanthate	Dow 250[4]	MIBC	Aero 70[5]	Ref. No.
Rougher							
Broughton, Quebec	n.s.	-	-	-	-	-	50
Brome Co., Quebec	50	-	-	-	-	-	51
East Malartic, Quebec	-	-	-	15	-	-	52
	-	-	-	15	-	-	52
Bakertalc, Quebec	-	-	-	94	-	-	54,55
Bakertalc, Quebec	-	-	-	47	-	-	58,59
	-	-	-	-	47	-	58,59
	-	-	-	-	-	52	58,59
Madoc, Ontario	-	-	200	-	-	-	60
Madoc, Ontario	75	-	-	-	-	-	61
	75	-	-	-	-	-	61
Madoc, Ontario	87	-	-	-	-	-	62
Madoc, Ontario	-	300[1]	-	-	-	-	64
Madoc, Ontario	-	300[2]	-	-	-	-	66,67
Madoc, Ontario	45	-	-	-	-	-	68
Madoc, Ontario	30	160[3]	-	-	-	-	83
	15	125[3]	-	-	-	-	83
Deloro, Ontario	50	-	-	-	-	-	69
Deloro, Ontario	50	-	-	-	-	-	70
Deloro, Ontario	-	-	-	-	-	200	70
Deloro, Ontario	50	-	-	-	-	-	71
Deloro, Ontario	50	-	-	-	-	-	72
Deloro, Ontario	40	-	-	-	-	-	81
Deloro, Ontario	25	-	-	-	15	-	84
Grimsthorpe, Ontario	50	-	-	-	-	-	73
Matheson, Ontario	168	-	-	-	-	-	74
Matheson, Ontario	50	-	-	-	-	-	82
Adams, Ontario	56	-	-	-	-	-	75
	60	-	-	-	-	-	75
Tweed, Ontario	-	-	-	100	-	-	85
	-	-	-	100	-	-	85
	-	-	-	100	-	-	85
Cranberry Portage, Man.	100	-	-	-	-	-	76
Cranberry Portage, Man.	50	-	-	-	-	-	77
	50	-	-	-	-	-	77
Nahatlatch River, B.C.	110	-	-	-	-	-	79
Quensel, B.C.	-	-	-	-	72	-	39
	-	-	-	-	72	-	39
Cleaner							
Brome Co., Quebec	25	-	-	23	-	-	51
Bakertalc, Quebec	-	-	-	5	-	-	54,55
Bakertalc, Quebec	-	-	-	-	-	-	58,59
	-	-	-	-	5	-	58,59
	-	-	-	-	-	7	58,59
Madoc, Ontario	-	400[1]	-	-	-	-	64
Grimsthorpe, Ontario	25	-	-	-	-	-	73

[1]Armac 12 D
[2]Arquad 12
[3]Arquad T-50
[4]Dowfroth 250
[5]Aerofroth 70

The modifiers and depressants used included sodium carbonate, sodium silicate, sodium hydroxide, calgon, quebracho and starch. The choice of modifying agents, specifically depressants, was determined by the presence of specific gangue minerals.

The function of sodium carbonate was chiefly for pH and water hardness control. Sodium carbonate was also used to depress calcite by the formation of surface carbonation. The effect on magnesite and dolomite might reasonably be assumed to be similar.

Sodium hydroxide was also used for pH control and, to some extent, slime dispersion. Slime dispersion or peptizing, however, was chiefly effected by sodium silicate. Sodium silicate was also used to depress quartz and calcite. The depression of quartz by sodium silicate is considered to be due to the formation of silicic acid gel on the quartz surface.

Calgon or sodium hexametaphosphate is a sequestering agent, either removing or blocking calcium and magnesium ions in water.

Quebracho, as a depressant for calcite, is well documented. Quebracho, a derivative of tannin, has substituted sulphonic acid groups that solubilize the tannin. The tannin then reacts with calcium ions on the calcite surface to form calcium tannate complexes which result in depression of calcite.

Starch is used as a depressant in many mineral systems. Starches are negatively charged, and calcite is effectively depressed in their presence.

Calcium hypochlorite is a very powerful oxidising agent, and probably acts as a depressant for carbonaceous minerals. Calcium hypochlorite is also a strong germicidal agent and will destroy any activating organic matter on the surface of talc.

A summary of modifier concentration data for talc flotation is reported in Table 21.

Flotation retention times varied between 6 and 16 min, and were significantly related to particle size. The fastest retention time was for the coarsest size talc, 600 μm (79), and the slowest retention time for very fine talc, 48% minus 44 μm, (58). Flotation was conducted usually at natural pH, which was between pH 8.5 and 9.6, although one study was conducted at pH 12.1 (39). The achievement of high grades was possible by multi-stage cleaning, and generally impurity levels were low, e.g., 0.4% Fe and $<$1.00% CaO.

A summary of principal parameter data for talc flotation is reported in Table 22.

Pyrophyllite

Pyrophyllite is generally concentrated by straightforward crushing and screening techniques to produce various grades of product. Pyrophyllite from Manuels, Newfoundland, contains a significant percentage of quartz, so that alternative techniques, specifically flotation, were required for effective beneficiation. The grind size for most pyrophyllite flotation studies was between 210 and 44 μm. Pyrophyllite, as with talc, is also naturally floatable requiring only a frother for flotation. The frother generally employed was Pine Oil with additions between 100 and 150 g/t in one investigation (88). A cationic collector, Amine 220E, was employed in another investigation with a higher collector concentration of 400 g/t (91). A summary of modifier and collector concentration data for pyrophyllite flotation is reported in Table 23.

The modifiers and depressants used to aid pyrophyllite flotation included sodium carbonate, sodium silicate, quebracho and hydrofluoric acid. The function of sodium carbonate, sodium silicate and quebracho are the same as when they were used for talc flotation. A summary of principal parameter data is reported in Table 24.

Table 21 - Summary of modifier concentration data in g/t for talc flotation

Deposit location	Na_2CO_3	Na_2SiO_3	$CaOCl_2$	Calgon	Quebracho	Starch	Ref. No.
Rougher							
Broughton, Quebec	n.s.	-	-	-	n.s.	-	50
Brome Co., Quebec	375	-	-	-	-	-	51
East Malartic, Quebec	200	500	-	-	-	-	52
	250	500	-	-	-	-	52
Madoc, Ontario	500	n.s.	-	-	-	-	60
Madoc, Ontario	375	-	-	-	-	-	61
	750	-	-	-	250	-	61
Madoc, Ontario	750	-	-	-	-	-	62
Madoc, Ontario	-	-	-	400	-	-	64
Madoc, Ontario	500	-	-	-	-	250	66,67
Madoc, Ontario	400	400	-	-	-	-	83
	-	1250	-	-	-	-	83
Grimsthorpe, Ontario	350	-	-	-	-	-	73
Tweed, Ontario	n.s.[1]	-	1000	1000	-	-	85
	-	-	1000	1000	-	-	85
	-	-	1000	1000	-	-	85
Cranberry Portage, Man.	200	-	-	-	300	-	76
Cranberry Portage, Man.	500	-	-	-	250	-	77
	500	-	-	-	250	-	77
Cleaner							
Brome Co., Quebec	-	250	-	-	-	-	51
East Malartic, Quebec	150	250[2]	-	-	-	-	52
	150	250[2]	-	-	-	-	52
Madoc, Ontario	-	-	-	1000	-	-	64
Madoc, Ontario	500	-	-	-	-	300	66,67
Grimsthorpe, Ontario	-	200	-	-	-	-	73
Cranberry Portage, Man.	-	200	-	-	150	-	76

[1]pH adjusted with NaOH

[2]Includes 159 g/t NaOH

n.s. - not stated

Table 22 - Summary of principal parameter data for talc flotation

Deposit location	Rougher			Cleaner			Ref. No.
	Grind size µm	Pulp density %	pH	Float time min	No. of cleaning stages	Float time min/stage	
Broughton, Quebec	n.s.	n.s.	n.s.	n.s.	-	-	50
Brome Co., Quebec	65%-75	n.s.	n.s.	n.s.	2	n.s.	51
East Malartic, Quebec	58%-75	n.s.	9.0	n.s.	2	n.s.	52
	80%-75	n.s.	9.0	n.s.	2[1]	n.s.	52
Bakertalc, Quebec	85%-50	18	9.2	8	4	6	54,55
Bakertalc, Quebec	48%-44	20	9.2	16[2]	3	18[2]	58,59
	59%-44	20	9.2	15[2]	3	15[2]	58,59
	59%-44	20	9.2	12[2]	3	14[2]	58,59
Madoc, Ontario	n.s.	n.s.	n.s.	5	1	5	60
Madoc, Ontario	90%-75	n.s.	n.s.	8[3]	1	6[3]	61
	90%-75	n.s.	n.s.	11[3]	2	8[3]	61
Madoc, Ontario	98%-75	17	n.s.	n.s.	2	n.s.	62
Madoc, Ontario	90%-180	8	n.s.	n.s.	1[1]	n.s.	64
Madoc, Ontario	n.s.	8	8.5	12	3	5	66,67
Madoc, Ontario	100%-200	21	9.0	10	3	6	68
Madoc, Ontario	100%-300	37	9.1	11	1	5	83
Deloro, Ontario	100%-150	n.s.	n.s.	6	-	-	69
Deloro, Ontario	100%-150	20	n.s.	n.s.	-	-	70
Deloro, Ontario	100%-300	17	n.s.	n.s.	2	n.s.	72
Deloro, Ontario	100%-150	15	n.s.	n.s.	n.s.	n.s.	84
Grimsthorpe, Ontario	65%-75	n.s.	n.s.	n.s.	1	n.s.	73
Matheson, Ontario	100%-75	11	n.s.	15	2	10	74
Matheson, Ontario	94%-44	16	9.6	n.s.	6	n.s.	82
Tweed, Ontario	62%-45	25	11.0	n.s.	3	n.s.	85
	61%-45	25	9.4	n.s.	3	n.s.	85
	61%-45	25	9.4	n.s.	3	n.s.	85
Nahatlatch River, B.C.	94%-600[3]	15[3]	n.s.	6	2	4	79
Quesnel, B.C.	80%-44	35[3]	12.1	10	4	6	39
	80%-44	35[3]	12.1	8	4	5	39

[1]Regrinding before cleaning

[2]Calculated

[3]Estimated

n.s. - not stated

Table 23 - Summary of modifier and collector concentration data in g/t for pyrophyllite flotation

Deposit location	Lot No.	Pine Oil	220E*	Na_2SiO_3	Na_2CO_3	Quebracho	HF	Ref. No.
Rougher								
Manuels	2	100	-	400	150	200	-	88
	3	150	-	400	200	-	-	88
Manuels	1	n.s.	-	-	-	-	n.s.	90
Manuels	1	-	400	650	-	-	-	91
	2	-	400	650	-	-	-	91
Cleaner								
Manuels	2	-	-	400	-	125	-	88
	3	-	-	400	-	-	-	88

*Amine 220E

Table 24 - Summary of principal parameter data for pyrophyllite flotation

Deposit location	Lot No.	Rougher			Cleaner		Ref No.
		Grind size µm	pH	Float time min	No. of cleaning stages	Float time min/stage	
Manuels	2	92%-44	8.0	6	1	6	88
	3	93%-44	7.9	7	1	7	88
Manuels	1	-150	n.s.	-	-	-	90
Manuels	1	-44	n.s.	n.s.	1	n.s.	91
	2	-210	n.s.	n.s.	1	n.s.	91

Miscellaneous Beneficiation Techniques

A variety of beneficiation techniques were employed to remove specific minerals. Thus talc was separated from rutile and pyrrhotite by spiral concentration (58); from dolomite by photometric sorting (65), air classification and wet tabling (60); and from tremolite by differential grinding (66). Acid leaching was employed in two studies to reduce the iron oxide content (58,68).

Air classification in combination with dry attrition scrubbing were used to separate quartz in pyrophyllite beneficiation (90).

CONCLUDING COMMENT

This report is the eighth in a Summary Report series on industrial minerals. These reports are designed to assist individuals or companies having interest in industrial minerals in Canada.

A wide distribution of the Summary Report series is planned as a means of encouraging interest in the further development of industrial minerals for use in many diverse applications. These uses vary from fillers for everyday products such as paint and rubber, to the high-technology sector for products such as high-performance plastics.

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APPENDIX 1

SUMMARIES OF CANMET TALC AND SOAPSTONE STUDIES

QUEBEC

Identification	:	Que.-1 (Ref. No. 49)
Report - Title	:	THE GRINDING OF A SOAPSTONE FROM ROBERTSONVILLE
- Author	:	R.K. Cornochan
- No. and Date	:	*Ore Dressing Investigation Report* 310 (1928)
Sample Description	:	A 1640 kg sample of greenish grey soapstone free from cracks, but having a laminated structure.
Objective	:	To determine the most suitable grinding method to reduce the soapstone to minus 44 μm, so that it could be used as a filler in paints, paper, rubber, textiles etc.; also to minus 250 μm so that it could be used in asphalt roofing shingles.
Processing	:	Crushing to minus 25 mm followed by three methods of size reduction: a) Hammer milling to pass 4.8 mm, followed by pebble milling and air classification. b) Hammer milling to pass 4.8 mm, followed by dry grinding in a Raymond Pulverizer. c) Hammer milling in closed circuit with a 250 μm screen.
Results	:	Each comminution method reduced soapstone to the required size, that is, minus 44 μm for methods a) and b), and minus 250 μm for method c). Minus 44 μm soapstone was white with a greyish tint, and minus 250 μm soapstone was greenish white.
Potential Use	:	The minus 44 μm soapstone is suitable for most filler applications and the minus 250 μm soapstone is suitable for roofing asphalt shingles.

Identification	:	Que.-2 (Ref. No. 50)
Report - Title	:	REPORT ON THE BENEFICIATION OF MADOC TALC AND BROUGHTON SOAPSTONE
- Author	:	G.A. Kirkendale
- No. and Date	:	*Ore Dressing Investigation Report* (unnumbered) (1942)
Sample Description	:	A sample of soapstone from Broughton, Quebec.
Mineralogy	:	Minor carbonates and iron oxide minerals analyzing 4.50% CaO, 0.76% Fe_2O_3 and 4.50% FeO.
Objective	:	To produce a talc product suitable for ceramic steatite manufacture.
Processing	:	Grinding to an unspecified size followed by flotation.
Results	:	Flotation reduced the CaO content to $<1\%$, but the iron oxide content could not be reduced to $<0.5\%$.
Potential Use	:	Not suitable for ceramic steatite manufacture.

Identification	:	Que.-3 (Ref. No. 51)
Report - Title	:	BENEFICIATION OF A TALC ORE FROM PIBUS, BROME CO.
- Author	:	H.L. Beer
- No. and Date	:	*Ore Dressing Investigation Report* 2296 (1947)
Sample Description	:	A 60 kg sample of high-grade talc ore.
Mineralogy	:	Analysis indicated 82.9% talc, 3.8% Fe as ferruginous chlorite, pyrite, limonite, ilmenite and magnetite.
Objective	:	To produce paper-grade talc.
Processing	:	Grinding, magnetic separation and flotation.
Results	:	Magnetic separation was not successful in improving the grade of talc. Flotation of feed material ground to 65% minus 75 μm successfully removed 80% of the acid soluble iron. The colour of the talc concentrate was distinctly lighter than the feed, but the total iron analysis was only reduced to 3.4% Fe.
Remarks	:	It was noted that the discolouring minerals were all acid soluble iron minerals, so that although the total iron was not significantly reduced, the final product was white.
Potential Use	:	Possibly suitable as paper-grade talc.

Identification	:	Que.-4 (Ref. No. 52)
Report - Title	:	RECOVERY OF TALC FROM ROCK AND TAILINGS OF EAST MALARTIC MINES LTD.
- Author	:	H.L. Beer
- No. and Date	:	*Industrial Minerals Report* 173 (1953)
Sample Description	:	A 150 kg sample of talc ore and a 40 kg sample of tailings.
Mineralogy	:	A head analysis of the talc ore sample indicated about 45% talc, 25% carbonates, 20% chlorite, 4% amphibole and 1.5% magnetite. The tailings sample analyzed about 35% talc, 17.5% chlorite, 12.5% hornblende, 5% magnetite and 10% carbonates.
Objective	:	To produce high-grade talc.
Processing	:	The ore sample was crushed to 1.2 mm and a portion ground to about 58 % minus 75 μm for flotation. The rougher concentrate was reground before cleaning. The tailings sample was 20.1% plus 75 μm, so that screening to remove the plus 210 μm fraction was necessary. Flotation was applied with regrinding of the rougher concentrate. Magnetic separation prior to flotation was also assessed on the tailings sample.
Results	:	Flotation of the talc ore sample produced a concentrate analyzing 0.29% Fe_2O_3 and 0.25% CaO with a weight recovery of 57.4%. Flotation of the tailings sample produced a concentrate analyzing 0.57% Fe_2O_3 and 0.33% CaO with a weight recovery of 53.8%. Magnetic separation prior to flotation was not successful in removing iron oxide minerals.
Potential Use	:	Each concentrated product was not white enough for paper manufacture, but each would be suitable as a filler in roofing tiles and rubber.

Identification	:	Que.-5 (Ref. No. 53)
Report - Title	:	ROLLS CRUSHING AND SCREENING TRIALS ON A SAMPLE FROM BAKERTALC
- Author	:	K.A. Wyman
- No. and Date	:	*Investigation Report* 58-122 (1958)
Sample Description	:	A 30 kg sample of coarse size feed, talc ore.
Mineralogy	:	Not stated.
Objective	:	To produce a crushed product less than 420 μm and not more than 40% minus 75 μm in size, with a minimum of minus 44 μm.
Processing	:	Rolls crushing and screening.
Results	:	After four passes with a very tight rolls setting, 86% minus 420 μm was recovered. The minus 75 μm was 21.9%, and the minus 44 μm, 16.2%.
Potential Use	:	Not applicable.

Identification	:	Que.-6 (Ref. No. 54,55)
Report - Title	:	A LABORATORY STUDY OF THE FLOTATION CIRCUIT AT BAKERTALC INC., HIGHWATER
- Author	:	P.R.A. Andrews
- No. and Date	:	*Division Report* 84-5 (CR) (1984)
Sample Description	:	A 50 kg sample of pre-ground flotation feed, 85% minus 50 μm in size, and a 15 kg sample of coarse hammer mill discharge, minus 25 mm in size.
Mineralogy	:	Carbonaceous, serpentinized talc analyzing about 60% talc, 36% magnesite and dolomite, and 4% total iron as ferruginous magnesite and chlorite. Trace minerals included calcite and pyrite, and the liberation size was about 200 μm.
Objective	:	To produce paper-grade talc.
Processing	:	Magnetic separation and flotation.
Results	:	Flotation produced a concentrate analyzing 96% talc with a recovery of 66% and a brightness of 86%. Magnetic separation was only partially successful in reducing the iron oxide content. Flotation of hammer mill discharge ground to 70% minus 50 μm indicated that comparable results to pre-ground ore could be obtained, which indicated that it was not necessary to grind to 85% minus 50 μm for liberation of talc.
Potential Use	:	Suitable as paper-grade talc.

Identification	:	Que.-7 (Ref. No. 56,57)
Report - Title	:	PLANT STUDY OF THE FLOTATION CIRCUIT AT BAKERTALC, HIGHWATER
- Author	:	P.R.A. Andrews
- No. and Date	:	*Division Report* 85-2 (CR) (1985)
Sample Description	:	Fourteen selected 1 to 2 kg samples of the plant flotation circuit.
Objective	:	To ascertain whether the present plant flotation cells had enough capacity to process 3.36 t.p.h of feed material (an increase of 100% of the present feed rate).
Processing	:	Sampling every hour over an 8-h period at key sampling points. Each sample was weighed wet, filtered, weighed dry, and analyzed for acid insoluble and total iron.
Results	:	By calculation of the pulp densities and a computer-aided mass balance, the various flotation retention times were calculated. The various retention times were compared to required retention times. The required retention times were based on laboratory testwork results, with the application of scale-up factors for converting laboratory to plant conditions.
Remarks	:	The basic conclusion was that additional flotation cell capacity would be required to accommodate an increase in feed rate from 1.68 to 3.36 t.p.h.
Potential Use	:	Not applicable.

Identification	:	Que.-8 (Ref. No. 58,59)
Report - Title	:	OPTIMIZATION OF GRINDING AND FLOTATION PARAMETERS; PILOT PLANT TREATMENT OF QUEBEC TALC ORE
- Authors	:	P.R.A. Andrews and J.P. Rouleau
- No. and Date	:	*Division Report* 87-120 (IR) (1987)
Sample Description	:	5 t of pre-ground flotation feed, 85% minus 44 μm in size; and 5 t of hammer mill discharge, minus 25 mm in size.
Mineralogy	:	Similar to Division Report 84-5 (CR).
Objective	:	To produce cosmetic-grade talc.
Processing	:	Magnetic separation, spiral concentration, flotation and acid leaching. Hammer mill discharge sample was crushed and ground before flotation.
Results	:	A six-stage pilot plant circuit using Dowfroth 250 collector produced a concentrate from pre-ground ore analyzing 97.2% talc, with a recovery of 57.9%. Hammer mill discharge ground to 48% minus 44 μm produced a concentrate analyzing 97% talc with a recovery of 75.9% using Dowfroth 250 collector. A superior result was obtained using Aerofroth 70 collector on ground hammer mill discharge, when a concentrate analyzing 96.4% talc, with a recovery of 78.2% was obtained. Magnetic separation and spiral concentration were only partially successful in reducing the iron oxide content. Acid leaching was more successful in reducing the iron oxide content, but only to 1.29%; the brightness value was 90%.
Potential Use	:	Not suitable as cosmetic-grade talc due to the high levels of Fe_2O_3, although the brightness value, at 90%, meets minimum requirements.

ONTARIO

Identification	:	Ont.-1 (Ref. No. 60)
Report - Title	:	EXPERIMENTAL TESTS ON MADOC TALC FOR THE SEPARATION OF DOLOMITE
- Authors	:	R.H. Carnochan and R.A. Rogers
- No. and Date	:	*Ore Dressing Investigation Report* 470 (1933)
Sample Description	:	A 90 kg sample of crude talc ore, consisting of large pieces of soft white talc containing small rounded aggregates of harder dolomite, about 6mm in size.
Mineralogy	:	The head analysis indicated 51.8% talc with major dolomite and minor iron oxide and alumina minerals. The CaO analysis was 5.70%.
Objective	:	To produce high-grade talc suitable for the paper industry.
Processing	:	Crushing, grinding and screening; grinding and air separation; wet tabling and flotation.
Results	:	Selective grinding was not very effective, and air classification using a Gayco air classifier reduced the CaO content by only 50%. Wet tabling reduced the CaO content in the minus 150 μm range by 60%, and flotation successfully reduced the CaO content by 90% to 0.32% CaO.
Potential Use	:	Possibly suitable for paper-grade talc, but too abrasive to be considered suitable as cosmetic grade.

Identification	:	Ont.-2 (Que.-2) (Ref. No. 61 and 50)
Report - Title	:	REPORT ON THE BENEFICIATION OF MADOC TALC AND BROUGHTON SOAPSTONE
- Author	:	G.A. Kirkendale
- No. and Date	:	*Ore Dressing Investigation Report* (unnumbered), 1942
Sample Description	:	Two samples of talc ore from Madoc, Ontario; Lot 1 - high grade, Lot 2 - low grade.
Mineralogy	:	Minor carbonates with iron oxide minerals; Lot 1 - analyzed 1.79% CaO, Lot 2 - 10.34% CaO.
Objective	:	To produce a talc product suitable for ceramic steatite manufacture.
Processing	:	Crushing to minus 1.2 mm, wet grinding in a ceramic mill to 90% minus 75 μm followed by flotation.
Results	:	Flotation of the high-grade ore produced a concentrate analyzing 0.35% CaO with a weight recovery of 51.8%. Flotation of the low-grade ore produced a concentrate analyzing 0.62% CaO. The weight recovery, however, was much lower at 23% than for the high-grade sample.
Potential Use	:	Both high and low-grade talc ores yielded products suitable for steatite bodies.

Identification	:	Ont.-3 (Ref. No. 62)
Report - Title	:	PILOT PLANT BENEFICIATION OF MADOC TALC
- Author	:	Anon.
- No. and Date	:	*Ore Dressing Investigation Report* (unnumbered), 1942
Sample Description	:	A 1 t sample of dry ground, air classified talc, 97.5% minus 75 μm, analyzing 8.38% CaO.
Objective	:	To produce a concentrated talc product suitable for steatite manufacture.
Processing	:	Flotation involved a rougher stage followed by two stages of cleaning; feed rate was 22 kg/h.
Results	:	A talc concentrate analyzing 1.76% CaO was obtained. Further cleaning could reduce the CaO level to $<1\%$, but with a much reduced recovery.
Potential Use	:	Not applicable.

Identification	:	Ont.-4 (Ref. No. 63)
Report - Title	:	CANADIAN TALC FOR USE IN STEATITE INSULATORS
- Authors	:	H.S. Spence, J.G. Phillips and W.T. Turrall
- No. and Date	:	*Reprinted from J. Am. Cer. Soc. Vol 22, No. 8* (1943)
Sample Description	:	A Madoc talc concentrate analyzing 95% talc containing 1.76% CaO, 0.29% Fe_2O_3 and 0.23% Al_2O_3 as impurities.
Objective	:	To determine suitability for steatite manufacture.
Processing	:	The beneficiated talc was tested by incorporating it in the following body formula: talc 90%, potash feldspar 5%, and plastic kaolin 5%. Yellow potato dextrin was used as a binder, and test pieces were prepared by pressing at 2,461 $t.m^{-2}$ with a moisture content of 5%. A sample of California talc with a similar analysis was prepared in an identical manner for purposes of comparison. The test pieces were fired to several different temperatures.
Results	:	The body prepared from beneficiated Madoc talc presented no difficulties in pressing and showed no signs of being abrasive. After firing, bodies containing Madoc talc exhibited a pure white colour that was much whiter than the bodies containing the California talc. The Madoc talc, however, required a higher firing temperature than California talc to reach vitrification. Subsequent tests on dielectric properties of bodies prepared from each talc sample indicated that when an equal degree of vitrification was attained, the dielectric properties were similar. Madoc talc was also tested for refractoriness and determined to be more refractory than California talc.
Potential Use	:	Suitable for the steatite electrical insulator industry.

Identification	:	Ont.-5 (Ref. No. 64)
Report - Title	:	FLOTATION OF MADOC TALC FROM DOLOMITE
- Author	:	R.A. Wyman
- No. and Date	:	*Industrial Minerals Test Report* 58-124 (1958)
Sample Description	:	A 90 kg sample of coarse dolomitic talc ore.
Mineralogy	:	Head analysis indicated 50% talc and 50% dolomite.
Objective	:	To produce a high-grade talc suitable for paper manufacture.
Processing	:	Crushing to 4.8 mm, rolls crushing to 420 μm, grinding to 90% minus 180 μm followed by flotation.
Results	:	A high-grade 97.2% talc concentrate was obtained after regrinding to 70% minus 44 μm. The recovery was reported as 64.1%.
Potential Use	:	Suitable for paper-grade talc.

Identification	:	Ont.-6 (Ref. No. 65)
Report - Title	:	PHOTOMETRIC SORTING OF TALC FROM MADOC
- Author	:	R.A. Wyman
- No. and Date	:	*Mineral Processing Test Report* 69-4 (1969)
Sample Description	:	Three, 25 kg samples of coarse, 75 mm lumps of dolomitic talc.
Mineralogy	:	The head analysis was not stated, but talc was the major mineral with minor dolomite and tremolite.
Objective	:	To produce high-grade talc.
Processing	:	Screening into minus 12.7 plus 9.6 mm and minus 9.6 plus 6.3 mm fractions, followed by photometric sorting of each size fraction.
Results	:	Separation of dolomite by photometric sorting appeared to be encouraging but no grades or recoveries were reported.
Potential Use	:	Not determined.

Identification	:	Ont.-7 (Ref. No. 66,67)
Report - Title	:	REDUCTION OF FIBROUS CONTENT OF TALC FROM MADOC
- Author	:	R.A. Wyman
- No. and Date	:	*Unpublished Results* (1974)
Sample Description	:	Carbonaceous, tremolite-talc schist.
Mineralogy	:	The head analysis was estimated by binocular microscope to be 50% talc, 20% dolomite, 15% tremolite, 10% serpentine and 5% muscovite.
Objective	:	To produce paper-grade talc.
Processing	:	Electronic ore sorting, differential grinding and flotation.
Results	:	Differential grinding separated 70% of the tremolite in the plus 6.4 mm product, leaving 70% of the talc in the minus 6.4 mm product. Flotation produced a concentrate analyzing 88% talc and 7% tremolite, with a recovery of only 46.9%.
Potential Use	:	Further beneficiation would be necessary for the production of paper-grade talc.

Identification	:	Ont.-8 (Ref. No. 68)
Report - Title	:	A BENEFICIATION STUDY OF TREMOLITIC TALC FROM CANADA TALC INDUSTRIES, MADOC
- Authors	:	P.R.A. Andrews and J.A. Soles
- No. and Date	:	*Division Report* 85-6 (CR) (1985)
Sample Description	:	A 60 kg sample of minus 50 mm carbonaceous tremolite schist from the East Pit deposit.
Mineralogy	:	Scanning electron microscopy indicated a head analysis of 52% talc, 18% calcite/dolomite, 10% tremolite and 10% quartz, with minor chlorite, feldspar and iron oxides. The liberation size of talc was determined at 200 μm.
Objective	:	To produce paper-grade talc.
Processing	:	Magnetic separation and flotation of feed material ground to minus 210 μm, with acid leaching of the final concentrate.
Results	:	Flotation produced a concentrate analyzing 95% talc, 5% calcite/dolomite and <1% tremolite. The recovery was not stated.
Potential Use	:	Possibly suitable as paper-grade talc.

Identification	:	Ont.-9 (Ref. No. 69)
Report - Title	:	CONCENTRATION OF MAGNESITE FROM DELORO TWP: PROGRESS REPORT NO. 1
- Author	:	F.H. Hartman
- No. and Date	:	*Internal Report* 63-61 (1963)
Sample Description	:	A 750 kg sample of minus 250 mm talc-magnesite ore. The mineralogical composition was 57% magnesite, 23% talc, 15% quartz, with minor iron oxide minerals.
Objective	:	To produce a marketable-grade concentrate.
Processing	:	Crushing to 4.8 mm for the separation of a head sample. Further crushing to 600 μm, followed by dry grinding in a ceramic-plate pulverizer to 150 μm. Flotation involved removal of a talc concentrate.
Results	:	A talc concentrate analyzing about 82% talc was obtained.
Remarks	:	Recovery and grade were not optimized.
Potential Use	:	Not determined.

Identification	:	Ont.10 (Ref No. 70)
Report - Title	:	CONCENTRATION OF MAGNESITE FROM DELORO TWP: PROGRESS REPORT NO. 3
- Author	:	F.H. Hartman
- No. and Date	:	*Investigation Report* 64-104 (1964)
Sample Description	:	A talc-magnesite ore with a mineralogical analysis of 57% magnesite, 23% talc, 15% quartz, with minor iron oxide minerals.
Objective	:	To optimize talc flotation by evaluation of different collectors.
Processing	:	Crushing to 600 μm, followed by dry grinding using a ceramic-plate pulverizer to 150 μm. Flotation of talc was assessed using Pine oil and an alcohol frother, Aerofroth 70. The procedure was directed towards maximum recovery rather than maximum grade.
Results	:	An 80% recovery of talc was obtained with each collector, but much less Pine oil (50 g/t) was required to achieve this recovery than with Aerofroth 70 (200 g/t). The grade with either collector was about 75% talc.
Remarks	:	Recovery and grade were not optimized.
Potential Use	:	Not determined.

Identification	:	Ont.-11 (Ref. No. 71)
Report - Title	:	CONCENTRATION OF MAGNESITE FROM THE TIMMINS AREA
- Author	:	F.H. Hartman
- No. and Date	:	*Investigation Report* 65-4 (1965)
Sample Description	:	A 100 kg sample of minus 150 mm lumps of a talc-magnesite ore with minor amounts of chlorite, mica and specularite. Mineralogical analysis indicated 48% talc, 38% magnesite, 12% hematite and 2% quartz.
Objective	:	To produce a marketable-grade talc concentrate.
Processing	:	Crushing to 4.8 mm for the separation of a head sample. Further crushing to 600 μm was followed by dry grinding in a ceramic-plate pulverizer to 150 μm. Flotation involved removal of a talc concentrate.
Results	:	A talc concentrate analyzing about 90% talc was obtained but with a low recovery.
Remarks	:	Recovery was not optimized.
Potential Use	:	Not determined.

Identification	:	Ont.-12 (Ref. No. 72)
Report - Title	:	PILOT PLANT CONCENTRATION OF TALC FROM DELORO TWP.
- Author	:	R.A Wyman
- No. and Date	:	*Investigation Report* 71-2 (IR) (1971)
Sample Description	:	A 270 kg sample of magnesite ore containing some talc.
Mineralogy	:	The head analysis indicated 57% magnesite, 23% talc, 15% quartz and 5% as chlorite, with minor calcite and miscellaneous oxide and sulphide minerals.
Objective	:	To establish whether the talc could be used for ceramic purposes.
Processing	:	Jaw crushing to 19 mm, cone crushing to 600 μm with rejection of plus 600 μm which did not contain talc; further differential grinding to 300 μm with rejection of plus 300 μm which did not contain talc. The minus 300 μm fraction was used as feed for pilot-scale flotation. Magnetic separation was used to separate iron oxide minerals from talc flotation concentrates.
Results	:	Flotation produced a concentrate analyzing 93.8% talc and 0.55% Fe_2O_3. Magnetic separation of the talc flotation concentrate increased the talc content to 96.9%, and reduced the iron oxide content to 0.26%. The recovery after magnetic separation was 66.8%; the brightness of the talc concentrate was 85%.
Potential Use	:	Not determined for ceramic manufacture, but grade and brightness of the talc concentrate would indicate suitability as paper-grade.

Identification	:	Ont.-13 (Ref. No. 73)
Report - Title	:	BENEFICIATION OF TALC ORE FROM GRIMSTHORPE
- Author	:	H.L. Beer
- No. and Date	:	*Ore Dressing Investigation Report* (unnumbered) 1948
Sample Description	:	A 4 kg drill core sample.
Mineralogy	:	The head analysis indicated 56.3% talc, 2.18% Fe, and about 20% carbonate minerals.
Objective	:	To produce high-grade talc.
Processing	:	Crushing, grinding to 65% minus 75 μm and flotation.
Results	:	A flotation concentrate analyzing 92.4% talc was obtained but with only a recovery of 38.5%.
Remarks	:	The sample was too small for a detailed evaluation of optimum grade and recovery.
Potential Use	:	Possible paper-grade talc

Identification	:	Ont.-14 (Ref. No. 74)
Report - Title	:	BENEFICIATION TRIALS ON TALC FROM MATHESON
- Author	:	R.A. Wyman
- No. and Date	:	*Mineral Processing Test Report* 72-9 (1972)
Sample Description	:	A 45 kg sample of 100 to 150 mm talc ore.
Mineralogy	:	The head analysis indicated about 55% talc with magnesite as the major, and magnetite as the minor gangue mineral.
Objective	:	To produce high-grade talc suitable for the paper industry.
Processing	:	Jaw crushing to 1.2 mm, grinding to 100% minus 75 μm, followed by flotation to produce a talc concentrate. The flotation concentrate was passed through a small wet high-intensity magnetic separator to remove magnetite.
Results	:	Flotation produced a talc concentrate with a brightness of 86.3%, which was increased to 88.2% after magnetic separation. Talc recovery was about 75-80%.
Potential Use	:	The brightness is high enough for paper-grade talc.

Identification	:	Ont.-15 (Ref. No. 75)
Report - Title	:	SOME BENEFICIATION TRIALS ON TALC FROM ADAMS TWP.
- Author	:	R.A. Wyman
- No. and Date	:	*Mineral Processing Test Report* 73-14 (1973)
Sample Description	:	A sample of drill core, weight and size not specified.
Mineralogy	:	Talc was identified as the major mineral; minor minerals were chlorite, carbonates and pyrrhotite.
Objective	:	To produce high-grade talc.
Processing	:	Crushing to 1.2 mm, grinding to 100% minus 75 μm, followed by flotation. A second series of tests involved grinding to 99% minus 300 μm, followed by magnetic separation to remove pyrrhotite; the non-magnetic fraction was further beneficiated by flotation.
Results	:	Flotation, as the only method of beneficiation, increased the brightness to 83.3%. The low brightness value was due to the presence of chlorite and pyrrhotite. Magnetic separation successfully removed the pyrrhotite but subsequent flotation could not increase the brightness value above 83.7%.
Remarks	:	Further beneficiation at a finer size might result in a higher brightness product.
Potential Use	:	Unsuitable as paper-grade talc.

MANITOBA

Identification	:	Man.-1 (Ref. No. 76)
Report - Title	:	CONCENTRATION OF TALC-MAGNESITE ORES FROM CRANBERRY PORTAGE
- Author	:	H.L. Beer
- No. and Date	:	*Ore Dressing Investigation Report* (unnumbered) (1951)
Sample Description	:	A 3 kg sample of talc-magnesite ore analyzing 43% talc, 52% magnesite and 5% iron oxide.
Objective	:	To produce separate talc and magnesite concentrates.
Processing	:	Crushing to 210 μm, followed by desliming and flotation of talc. The flotation tailings were dried and iron oxide minerals were removed by dry magnetic separation.
Results	:	A talc concentrate was obtained analyzing 0.43% Fe_2O_3 and 6.76% LOI, with a recovery of about 90%. The magnesite concentrate analyzed 4.38% Fe_2O_3 and 40.89% MgO, and represented a recovery of 86.1%.
Potential Use	:	The iron oxide levels of both the talc and magnesite concentrates are too high for most high-value applications.

Identification	:	Man.-2 (Ref. No. 77)
Report - Title	:	FURTHER CONCENTRATION OF TALC-MAGNESITE ORES FROM CRANBERRY PORTAGE
- Author	:	H.L. Beer
- No. and Date	:	*Ore Dressing Investigation Report* (unnumbered) (1952)
Sample Description	:	Two lots, A and B; lot A weighed 60 kg and analyzed 59% ferro-dolomite and breunerite, 39% talc and 2% magnetite; lot B weighed 55 kg and analyzed 44% ferro-dolomite and breunerite, 52% talc and 4% magnetite.
Objective	:	To produce separate talc and magnesite concentrates.
Processing	:	Grinding to 210 μm, followed by the recovery of talc and magnesite by flotation.
Results	:	A talc concentrate was produced from lot A material analyzing 2.8% Fe_2O_3 and 17.6% LOI, with a weight recovery of 56.9%. The talc concentrate produced from lot B material analyzed 2.9% Fe_2O_3, 18.4% LOI and represented a weight recovery of 57.9%. Very little magnesite was recovered, since the carbonaceous fraction of each lot was mainly ferro-dolomite.
Potential Use	:	The iron oxide content of the talc concentrates is too high for high-value applications.

BRITISH COLUMBIA

Identification	:	B.C.-1 (Ref. No. 78)
Report - Title	:	THE EVALUATION OF GROUND TALC FROM SILVER MOON, SOUTHEASTERN BRITISH COLUMBIA
- Author	:	J.E. Reeves
- No. and Date	:	*Investigation Report* 63-64 (1963)
Sample Description	:	An 11 kg sample of fine-ground talcose rock, 98% minus 44 μm in size, with a specific gravity of 2.78, and a Hegman fineness of 2.5.
Mineralogy	:	X-ray diffraction analysis indicated 95% talc with minor dolomite and mica.
Objective	:	To evaluate the sample for ceramic, paint pigment and paper filler use.
Processing	:	Firing tests were conducted at cone 1 (1136°C), cone 5 (1177°C) and cone 12 (1306°C). Paint pigment evaluation was assessed with reference to ASTM (American Society for Testing Materials) designated standards.
Results	:	The near-white colour and absence of discolourant particles in the samples fired to cone 1 and 5 indicated that the talc sample was potentially acceptable for certain ceramic uses. The PCE (pyrometric cone equivalent) was 15.5. The ASTM paint pigment test evaluation indicated that the chemical composition and physical characteristics were within specification limits. The Hunter colour meter indicated a brightness of 92%.
Potential Use	:	Suitable for wall tile, semi-vitreous dinner and artware. Suitability for the pigment-paint and paper-filler markets was also indicated.

Identification	:	B.C.-2 (Ref. No. 79)
Report - Title	:	CONCENTRATION TRIALS ON A TALC SAMPLE FROM NAHATLATCH RIVER FOR PACIFIC TALC
- Author	:	R.A Wyman
- No. and Date	:	*Mineral Processing Test Report* 73-13 (1973)
Sample Description	:	A 10 kg sample of magnesitic talc ore.
Mineralogy	:	The head analysis indicated 70.8% talc with major magnesite, and minor dolomite and chlorite as the contaminant minerals.
Objective	:	To produce high-grade talc.
Processing	:	Jaw crushing to 1.7 mm, followed by differential grinding to 600 μm. The low-grade plus 600 μm fraction which contained very little talc was discarded. The minus 600 μm fraction was beneficiated by flotation.
Results	:	Flotation produced a concentrate analyzing 97.8% talc for a recovery of 48.5%. The brightness of the concentrate was 86.7%.
Potential Use	:	The grade and brightness indicate suitability as paper-grade talc.

Identification	:	B.C.-3 (Ref. No. 80)
Report - Title	:	EVALUATION OF A DRILL CORE SAMPLE OF TALC FROM CHU CHUA
- Author	:	P.R.A. Andrews
- No. and Date	:	*Unpublished Results* (1985)
Sample Description	:	A 250 g sample of massive talc drill core.
Mineralogy	:	The drill core was mainly talc, and chemical analysis indicated 7.5% Fe_2O_3 as chlorite and 4.85% LOI as carbonates.
Objective	:	To qualitatively indicate suitability for various uses.
Processing	:	Since the sample was 250 g, only a limited preliminary evaluation was undertaken involving chemical analysis and brightness determinations.
Results	:	A brightness value of 77% was obtained on minus 44 μm material.
Remarks	:	Beneficiation by magnetic separation to reduce the iron oxide levels, and flotation to reduce the LOI levels are required before a serious evaluation of talc from this deposit can be made.
Potential Use	:	Not determined.

APPENDIX 2

SUMMARIES OF TALC AND SOAPSTONE STUDIES BY OTHER ORGANIZATIONS

ONTARIO

Identification	:	Ont.-16 (Ref. No. 81)
Report - Title	:	THE RECOVERY OF TALC FROM A TALC MAGNESITE ORE FROM NORTHERN ONTARIO
- Author	:	R.J.C. Tait
- No. and Date	:	*Lakefield Research Report* LR 920 (1963)
Sample Description	:	A 500 kg trench sample and various drill core samples of a talc-magnesite ore.
Mineralogy	:	The trench sample analyzed 29.98% MgO and 6.27% Fe_2O_3; the drill core samples 24.90% MgO and 5.72% Fe_2O_3. The mineralogical content was about 60% magnesite for the trench sample, and 50% magnesite for the drill cores.
Objective	:	To produce a high-grade talc product suitable for the pulp and paper industry.
Processing	:	Crushing to 850 μm, followed by grinding to 100% minus 210 μm; flotation and magnetic separation. The flotation processing route for each sample was flotation of talc, followed by flotation of silica leaving an enriched magnesite product as the flotation tailing.
Results	:	A talc concentrate analyzing 31.61% MgO, 62.24% SiO_2, 0.53% Fe_2O_3, which represented about 95% talc, was obtained.
Potential Use	:	Suitable for pulp and paper manufacture and for filler applications.

Identification	:	Ont.-17 (Ref. No. 82)
Report - Title	:	EVALUATION OF TALC FROM THE REEVES MINE, MATHESON
- Author	:	M.A.K. Grice
- No. and Date	:	*Unnumbered Report for Canadian Johns Manville* (1972)
Sample Description	:	A 7-t sample of lump talc ore, 75 to 200 mm in size.
Mineralogy	:	The head analysis was about 45% talc, 45% dolomite, 3% magnetite, with minor chlorite.
Objective	:	To produce high-grade talc.
Processing	:	Jaw crushing to 25 mm, followed by rolls crushing to 6 mm to provide feed for a 50 kg/h pilot plant at the Nova Scotia Technical College, Halifax. The pilot plant consisted of a ball mill in closed circuit with a classifier, and a six-stage cleaner flotation circuit. Grinding produced a feed to flotation of 94.0% minus 44 μm.
Results	:	The highest grade concentrate was 92.9% talc, but achieved at a weight recovery of only 10.3%. An intermediate grade of 87.7% talc at a weight recovery of 37.3% was also obtained.
Remarks	:	Brightness values were not determined, but the grey appearance of the concentrates would indicate the necessity for final removal of iron oxides by magnetic separation.
Potential Use	:	Possibly suitable as paper-grade talc, but further beneficiation was required to remove iron oxide contaminants.

Identification	:	Ont.-18 (Ref. No. 83)
Report - Title	:	EVALUATION OF MADOC TALC SAMPLES
- Author	:	E. Niskanen
- No. and Date	:	*Ortech International Report* X-72318, 1972
Sample Description	:	Three samples of talc ore designated pyritic, dolomitic, and contaminated talc; weight and size not specified.
Mineralogy	:	Analysis was not reported but the pyritic ore contained about 50% talc, the contaminated ore about 40% talc, and the dolomitic ore about 20%. The major contaminant mineral for each sample was dolomite; minor minerals included tremolite, antigonite, muscovite and pyrite.
Objective	:	To produce a high-grade product suitable for the paint industry.
Processing	:	Crushing to 1.7 mm, dry and wet screening at 300 μm, dry and wet grinding of the plus 300 μm oversize, followed by flotation. This procedure was used for the pyritic and contaminated samples. The dolomitic sample was dry ground to 210 μm.
Results	:	The dolomitic sample did not respond well to flotation. The best results were obtained with the pyritic ore, when a concentrate analyzing 1.6% LOI, and a weight recovery of 49.7% was obtained. The best result with the contaminated ore was a concentrate analyzing 3.0% LOI, with a weight recovery of 39.6%.
Potential Use	:	Paint evaluation tests were not conducted, but the pyritic ore may be suitable for the paper industry if the brightness value is high enough.

Identification	:	Ont.-19 (Ref. No. 84)
Report - Title	:	PILOT PLANT FLOTATION OF TALC AND MAGNESITE FROM TALC MAGNESITE ORE FROM NORTHERN ONTARIO
- Authors	:	R. Craig and C. Cox
- No. and Date	:	*Colorado School of Mines Report* 75-25 (1975)
Sample Description	:	A 2-t sample of talc magnesite ore.
Mineralogy	:	Major talc and magnesite with minor quartz, hematite and chlorite.
Objective	:	To produce specification-grade talc suitable for ceramic and paper applications.
Processing	:	Stage crushing to 3.4 mm by jaw and rolls crushers, followed by grinding to minus 150 μm. Flotation produced a talc rougher concentrate which was then reground to 80% minus 44 μm, followed by five stages of cleaning. A quartz concentrate was separated from the talc rougher tails leaving an enriched magnesite concentrate in the final flotation tails. Iron oxide minerals were removed before flotation by gravity concentration using a shaking table.
Results	:	A talc concentrate analyzing 95.6% with a recovery of 71.9% was obtained. The brightness value was determined as being 82%, and the Valley abrasion index was 69. Further recleaning reduced the abrasion index to 32.
Potential Use	:	Possibly suitable for ceramic and paper manufacture and for filler applications.

Identification	:	Ont.-20 (Ref. No. 85)
Report - Title	:	FLOTATION STUDY ON THREE TYPES OF TALC-CONTAINING ORE FROM TWEED
- Author	:	J. Kriens
- No. and Date	:	*IMD Laboratory Report* 90185 (1988)
Sample Description	:	Three samples of carbonaceous talc ore; samples 1 and 2 containing about 6% Fe_2O_3, and sample 3, 7.5% Fe_2O_3.
Objective	:	To produce marketable-grade talc from each sample.
Processing	:	Each sample was stage-crushed to pass 1.7 mm, followed by wet grinding in a ceramic-lined ball mill. Flotation involved a combined rougher and scavenger float, followed by three stages of cleaning. The talc concentrate from each sample, after flotation, was subjected to low and high-intensity wet magnetic separation to remove iron oxide minerals. Product evaluation involved brightness tests conducted on dry ground minus 45 μm concentrate.
Results	:	Sample 1 - a grade of 90% talc with a recovery of 30% and a brightness of 88%. Sample 2 - a grade of 90% talc with a recovery of 20% and a brightness of 90%. Sample 3 - a grade of 93% talc with a recovery of 40% and a brightness of 90%.
Remarks	:	Recoveries were not optimized.
Potential Use	:	Suitable for most filler applications, but the presence of 2 to 3% Fe_2O_3 in samples 1 and 2, and 4 to 5% Fe_2O_3 in Sample 3, restricts the use of these talc products from the higher value applications.

Identification : Ont.-21 (Ref. No. 86)

Report - Title : PRE-FEASIBILITY REPORT FOR PRODUCTION OF TALC AND MAGNESIA PRODUCTS FROM DELORO TWP.

- Author : R.A. Elliot
- No. and Date : *Unnumbered Report for Magnesium Refractories Ltd.* (1989)

Sample Description : A high-grade talc sample analyzing about 95%, with minor amounts of carbonaceous and alumino-silicate minerals.

Objective : To determine whether the talc sample was suitable for the major applications of talc.

Processing : Sizing, chemical analysis, brightness, abrasion, specific gravity, colour, absorption and ceramic testing determinations.

Results :

Colour - slight greenish tint
Particle structure - platey
Asbestiform materials - none
Brightness - 87% at 91.2% minus 44 μm

Loose bulk density	-	375 kg/m^3
Tapped density	-	770 kg/m^3
Specific gravity	-	2.79
pH	-	8.1 to 9.6
Valley abrasion test	-	9 to 25 on top quality
Oil absorption reading	-	24 (rub-out method)

Ceramic Properties

Fired colour	-	light cream
P.C.E.	-	15
D.T.A.	-	no major impurities
Dielectric properties	-	D-0.25 at 10 Kcs.

Analyses

SiO_2	-	59.8%	CaO	-	.005%	Cr	-	.025%
MgO	-	31.9%	Na_2O	-	.004%	Pb	-	<.002%
Fe_2O_3	-	.44%	Ni	-	.81%	Co	-	.01%
Al_2O_3	-	.77%	LOI	-	.32%	As	-	1.6 ppm

Potential Use : Suitable for use in cosmetics, pitch control in paper making, pharmaceuticals, plastics and paints. It may also be marketable for general ceramic use, although the high nickel content adversely affects its dielectric properties for electronic ceramics.

BRITISH COLUMBIA

Identification	:	B.C.-4 (Ref. No. 87)
Report - Title	:	EVALUATION OF BLOCK STEATITE FROM SILVER MOON, MOUNT WHYMPER
- Author	:	H. Thurnover
- No. and Date	:	*American Lava Corp.* (Unnumbered Report) (1942)
Sample Description	:	A block sample of steatite talc; weight and size not specified.
Mineralogy	:	Not specified.
Objective	:	To ascertain suitability for ceramic steatite manufacture.
Processing	:	The block sample was fired at 1093°C; several cracks developed which indicated that block form was unsuitable. The material in powdered form was pressed and fired to vitrification at 1371°C.
Results	:	The fired pieces produced from powdered material had a uniformly white colour.
Potential Use	:	The talc in powdered form probably would be suitable for steatite production.

Identification	:	B.C.-5 (Ref. No. 39)
Report - Title	:	BENEFICIATION AND EVALUATION OF TWO TALC-BEARING SAMPLES FROM QUESNEL
- Author	:	C.A. Booth
- No. and Date	:	*Ortech International Report* IMS 63-40334-85 (1985)
Sample Description	:	Two, 25-kg samples of talc ore; sample A described as peridotite, and sample B as platy talc. Each comprised about 60 to 70% talc, and 20% dolomite with minor chlorite.
Objective	:	To produce a concentrate suitable for pitch control in the pulp and paper industry.
Processing	:	Each sample was crushed to pass 6 mm and dry ground to liberation at 80% minus 44μm. Following size reduction, each sample was subjected to a locked-cycle flotation test, and the concentrates from each sample were further cleaned by wet high-intensity magnetic separation. Product evaluation involved particle size analysis, brightness, oil absorption and specific gravity determinations.
Results	:	Brightness determinations were 69.5% for the peridotite-concentrated talc, and 74.5% for the platy concentrated talc.
Potential Use	:	Probably suitable for pitch control.

APPENDIX 3

SUMMARIES OF CANMET PYROPHYLLITE STUDIES

C-107

NEWFOUNDLAND

Identification	:	Nfld.-1 (Ref. No. 88)
Report - Title	:	FLOTATION TESTS ON A SAMPLE OF PYROPHYLLITE FROM MANUELS
- Author	:	H.L. Beer
- No. and Date	:	*Mineral Dressing Investigation Report* 2750 (1951)
Sample Description	:	Three samples: sample 1, 220 kg of virtually pure pyrophyllite with trace zoisite; sample 2, 220 kg of dump material analyzing 80% pyrophyllite with zoisite and clinozoisite; sample 3, 445 kg of mine ore analyzing about 80% pyrophyllite with zoisite and clinozoisite. The pyrophyllite was fine-grained, foliated and slightly fibrous.
Objective	:	To produce a concentrate suitable for the filler industry.
Processing	:	Sample 1 was crushed to 1.2 mm, and dry ground in a Raymond mill to 94% minus 44 μm. Samples 2 and 3 were each crushed to minus 1.2 mm, ground to 94% minus 44 μm, followed by flotation to remove iron oxide.
Results	:	Flotation reduced the iron oxide content of samples 2 and 3 to about 0.02% acid soluble iron oxide. The beneficiated pyrophyllite was satisfactory as to colour, texture and slip. Recovery of pyrophyllite for sample 2 was 64%, and for sample 3, 84%.
Potential Use	:	Possibly suitable for filler applications.

Identification	:	Nfld.-2 (Ref. No. 89)
Report - Title	:	PROGRESS REPORT ON BENEFICIATION OF A PYROPHYLLITE SAMPLE
- Author	:	R.A. Wyman
- No. and Date	:	*Industrial Minerals Report* No. 472 (1957)
Sample Description	:	A 230 kg sample analyzing about 62% pyrophyllite and 38% quartz. The quartz occurs mainly as minus 150 μm fines.
Objective	:	To produce a concentrate suitable for tile manufacture.
Processing	:	Crushing to 850 μm, followed by air separation of fine material. The classified product was subjected to a series of abrasion trials using hard and soft grinding media. Further grinding was extended to 90% minus 75 μm, followed by flotation.
Results	:	Initial indications were that rubber balls were the best grinding media. Flotation produced a concentrate analyzing 3.43% LOI, with a pyrophyllite weight recovery of 62%.
Potential Use	:	Not determined.

Identification	:	Nfld.-3 (Ref. No. 90)
Report - Title	:	BENEFICIATION OF PYROPHYLLITE FROM NEWFOUNDLAND
- Author	:	R.A. Wyman
- No. and Date	:	*Investigation Report* 58-19 (1958)
Sample Description	:	The same as for the previous study.
Objective	:	To produce a concentrate suitable for tile manufacture.
Processing	:	Crushing to 1.2 mm, followed by dry grinding using various types of rubber grinding media. The minus 150 μm fines were removed by dry air classification. Crushing to 420 μm, followed by wet attrition and wet classification methods. Crushing to 840 μm, followed by a combination of dry classification and wet attritioning. The wet classified product was finally processed by wet screening to discard the minus 210 μm fraction. Flotation of material ground to 150 μm.
Results	:	Dry grinding with rubber balls produced a concentrate analyzing 2.39% LOI. The combination of dry classification and wet attritioning and classification, with wet screening, produced a concentrate analyzing 1.78% LOI. A combination of air classification, dry attritioning, wet grinding and flotation, resulted in a pyrophyllite product analyzing 4.08% LOI, with a recovery of 71%.
Potential Use	:	Possibly suitable for tile manufacture.

Identification	:	Nfld.-4 (Ref. No. 91)
Report - Title	:	BENEFICIATION INVESTIGATION OF PYROPHYLLITE-BEARING ROCKS FROM MANUELS.
- Author	:	W.J.D. Stone
- No. and Date	:	*Investigation Report* 58-157 (1958)
Sample Description	:	Three samples: Sample 1, 220 kg greyish-white, 50 to 75 mm fragments, analyzing about 40% pyrophyllite, 50% quartz with minor muscovite, paragonite and kaolinite. Sample 2, 220 kg of elongated yellowish-green fragments analyzing about 45% pyrophyllite, 45% muscovite with minor paragonite, kaolinite and quartz. Sample 3, 45 kg of fine white powder analyzing about 65% pyrophyllite, 25% quartz with minor muscovite, paragonite and kaolinite.
Objective	:	To produce a concentrate analyzing >20% Al_2O_3, and <1% $Na_2O + K_2O$.
Processing	:	Only samples 1 and 2 were processed; each was crushed, dry ground and subjected to flotation. Flotation of sample 2 was conducted at minus 210 μm, and flotation of sample 1 at minus 44 μm.
Results	:	The best results obtained using sample 2 material was a product analyzing 1.90%($Na_2O + K_2O$) and 29.26% Al_2O_3, which represented a pyrophyllite grade of 79.5%; recovery was 40.3%. The best results obtained using sample 1 material was a product analyzing 0.15%($Na_2O + K_2O$) and 20.43% Al_2O_3, which represented a recovery of 64.5%.
Potential Use	:	Sample 1 is possibly suitable for certain filler applications.

BRITISH COLUMBIA

Identification	:	B.C.-1 (Ref. No. 92)
Report - Title	:	GRINDING TESTS ON A SAMPLE OF PYROPHYLLITE FROM SEMLIN
- Author	:	C.H. Freeman
- No. and Date	:	*Ore Dressing Investigation Report* 2435 (1948)
Sample Description	:	A 130 kg sample, 50 to 100 mm in size, light grey in colour, with some lumps displaying a yellow to brownish iron-stained material. The sample was high grade, analyzing about 90% pyrophyllite with minor quartz.
Objective	:	To produce a ceramic or filler-grade material.
Processing	:	Hand picking to remove the worst iron-stained material, and screening to remove the minus 1.2 mm fraction which was also iron stained. The remaining sample was crushed to minus 1.2 mm using a steatite-faced jaw and rolls crusher, and the minus 1.2 mm fraction ground to 90% minus 44 μm in a ceramic-lined pebble mill.
Results	:	Firing tests were conducted in an electric furnace at 1310 and 1520°C. The resulting products showed no fusion or discolouration.
Potential Use	:	Suitable for ceramic or filler use.

APPENDIX 4

SUMMARY OF A PYROPHYLLITE STUDY BY ANOTHER ORGANIZATION

NEWFOUNDLAND

Identification	:	Nfld.-5 (Ref. No. 93)
Report - Title	:	PROCESSING OF SELECTED SAMPLES OF PYROPHYLLITE ORE FROM THE AVALON PENINSULA
- Authors	:	G.R. Guillet, J. Kriens, and P.E. Kriens,
- No. and Date	:	*MDA Report* (1987)
Sample Description	:	Chemical analyses and mineralogical descriptions are reported in Table 8.
Objective	:	To produce pyrophyllite products of acceptable purity suitable for common and potential industrial uses.
Processing	:	Crushing to 600 μm and grinding to about 75% minus 45 μm, followed by flotation. Two flotation processes were evaluated; flotation of sericite from pyrophyllite, and flotation of pyrophyllite from quartz, using a cationic collector at pH 2.5.
Results	:	An effective separation of pyrophyllite could not be made from either sericite or quartz. The calculated grade of pyrophyllite by each method, was 74.2% for separation from sericite, and 69.6% for separation from quartz.
Remarks	:	The quartz was not completely liberated in either separation.
Potential Use	:	Suitable only for established uses.